JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIV. OCTOBER, 1892. NO. 4

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

FISKE'S ELECTRICAL RANGE FINDER.

[*Report of the Committee on Science and the Arts.*]

[No. 1,655.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 1, 1892.

The Sub-Committee of the Committee on Science and the Arts, to whom was referred for examination

FISKE'S ELECTRICAL RANGE FINDER,

respectfully report that: The said invention is the subject of United States Letters-patent Nos. 406,829, 406,830, 418,910 and 444,217, granted to Bradley Allan Fiske, Lieutenant United States Navy.

These patents cover a new method of finding the range and position of a distant object quickly and with sufficient accuracy for directing guns on a distant target, either from a man-of-war or harbor fortification.

In naval warfare at the present day, where the ships are equipped with long-range guns of large calibre and the hulls lie so low in the water that they present an inconspicuous surface for a target, and the powerful engines with which they are propelled enable them to change their position rapidly, the necessity for some approximately accurate method of promptly determining the distance of the enemy's ship is an urgent one. In the language of one of the most distinguished officers of the British Navy: "No one knows what will happen in a naval action now, no chance should be thrown away. In these days, where it is possible for one shot to win an action, a ship fitted with an accurate range finder must have an enormous advantage over a ship not so fitted."

Prior to Lieutenant Fiske's invention, no satisfactory way of determining the distance of the enemy's ship had ever been devised. Many methods had been suggested and practised, but all were open to the objections:

(1) That the observations from which the calculations were made were not accurate enough.

(2) That the positions were changed by the time the calculations were completed.

To meet the latter objection it was customary to assume the position where the target would be by the time the calculations would have been completed; this introduced a new source of error. The method usually adopted was to station one observer at each end of a base line of known length to obtain by observation the angles at their respective ends between the base line and the object to be fired at, the observers communicating to each other either by visual or telegraphic signals; with the two angles thus observed and the known base line the distance from either observer could be calculated. Another method was to make a calculation of the time required for the sound of a gun fired from the enemy's ship to reach the observer. Small tubes, filled with sand, like hour glasses, which would register in seconds, were turned at the moment of observing the puff of smoke; the number of seconds elapsing between the puff and the report multiplied by the known

velocity of sound would give, roughly, the distance. It is obvious that after the second or third shot such a method would be valueless, as it would be impossible to identify the puff with a report.

A third method was to send an observer to the mast-head with a sextant to find the angle between the horizontal plane passing through the sextant and the line joining the sextant with the object whose distance was to be measured. From tables the distance corresponding to this angle was given to the captain of the gun.

The problem has been solved in a most interesting way by Lieutenant Fiske, who has made a most ingenious application of an electrical principle in the construction of his apparatus. The method, briefly stated, is as follows: Two observers are stationed at the ends of a base line of known length; each observer directs a telescope pivoted at the end of the base line upon the object whose distance is to be measured; the lines of sight of these telescopes will then correspond respectively with the two sides of a triangle of which the known base line is the base; by the movement of these telescopes the needle of a galvanometer is made to move over a scale, and a third observer, stationed at any convenient point (say at the gun, or in the chart room), reads off the length of one of the sides of the triangle in feet, the distance sought.

The principle of the invention consists in first determining a fractional portion of a conducting body bearing in length a ratio to the angle included between two lines of sight directed upon a distant object, and second, measuring the electrical resistance of said length. This is accomplished automatically, and the result given, as above stated, by means of an apparatus which is practically a Wheatstone bridge, the variable resistances in the members of which are arcs upon which move sliding contacts corresponding with the movements of the telescopes.

The following full description of the operation of the instrument is taken from Patent No. 444,217:

Referring to the accompanying *Fig. 1*, let *A B* be a base line and *T* the position of a distant object, the range of

which $A\ T$ is to be determined by trigonometry. In the triangle $A\ T\ B$,

$$A\ T = \frac{A\ B \times \sin A\ B\ T}{\sin A\ T\ B}.$$

let C and D represent two telescopes or alidade arms, pivoted

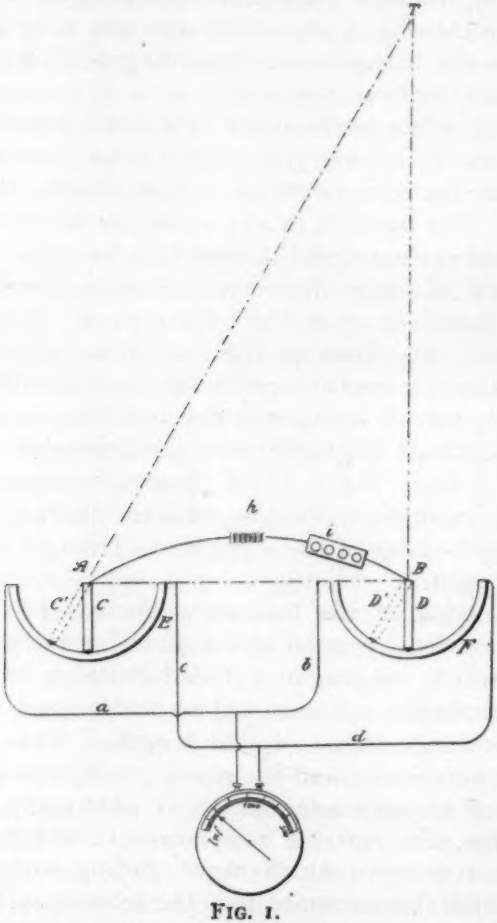

FIG. 1.

at the points A and B and sweeping over arcs E and F, of conducting material, the said arcs having their extremities upon the base line $A\ B$. Let the telescope C be directed upon the point T, assuming the position represented by C', dotted

lines. Then, obviously, the angle $C'\ A\ C$ is equal to the angle $A\ T\ B$, and the portion of the arc E included between the positions C' and C of the telescope will measure the angle at $A\ T\ B$.

In the foregoing formula the base line $A\ B$ is known by measurement and the angle $A\ B\ T$ is, as shown in the figure, a right angle, then the *sin* $A\ B\ T$ becomes unity. It remains, therefore, to find the angle $A\ T\ B$ in order to determine the distance $A\ T$, so that it becomes necessary to provide a simple and rapid means of at once determining what the angle $A\ T\ B$ is. To this end the arcs $E\ F$ of conducting material are connected in a Wheatstone bridge, the four members of which are shown, respectively, at *a b c d*. In this bridge a galvanometer *g* is connected in the usual way, and also the battery *h*, the terminals of the battery wire being connected to the telescopes at their pivot-points $A\ B$, so that the circuit proceeds through the telescopes to the arcs, and then at the arc F divides through the wires *b d* and at the arc E divides through the wires *a c*. It will be plain that when the two telescopes C and D stand at right angles to the base line, and hence parallel to one another, the bridge will balance and the galvanometer will show no deflection. The lines of sight of the two telescopes then being parallel the galvanometer will indicate infinite range; and of course this will be true no matter where the telescopes may be on their respective arcs, so long as their lines of sight are relatively parallel. But if one telescope be moved out of parallelism with the other—as, for example, the telescope C moved to the position C'—then clearly the bridge will be thrown out of balance and the galvanometer will be deflected. It will also be clear that the extent of deflection of the galvanometer will depend upon the length of arc included between the two positions of the telescope $C\ C'$, and will be greater as that arc increases, so that with a battery with constant electro-motive force it becomes possible to determine the extent of movement of the telescope C, by simply observing the indication of the galvanometer. It will of course be obvious that, as the angle between the positions C and C' of the telescope increases, the length of

the line *A T* will constantly decrease, while the deflection of the galvanometer will constantly increase, so that the galvanometer indicated ranges starting from infinity when the galvanometer shows no deflection, small ranges being indicated by large deflections of the galvanometer, and vice versa. As a matter of convenience, it is preferred to employ for this purpose a galvanometer so constructed that the deflections of the index will be proportional to the difference of potential at the terminals. The observer instantly reads the range from the galvanometer which is provided with a scale suitably marked in linear units, such as yards.

If, however, the angle *A B T* is not a right angle, then the factor *sin A B T* must be taken into consideration in solving the formula

$$A\ T = \frac{A\ B \times \sin A\ B\ T}{\sin A\ T\ B}$$

or, in other words, the observer at the galvanometer may simply multiply the range indication by the *sin A B T* numerically expressed in order to reduce the indicated range to the true range. The angle *A B T* is observed directly on the arc *F*.

In the above demonstration the resistance of the whole circuit is assumed to be constant or remains the same as when the two telescopes stand parallel to each other and touch the middle part of their respective arcs. As a matter of fact, however, the resistance of the whole circuit decreases as the telescopes approach the extremities of the arcs; this variation in resistance due to change of position will affect the total resistance in circuit to an extent depending upon its ratio to the resistance of the whole circuit. If this ratio be made very small, the variation may be rendered inappreciable. This is easily done by the insertion of a high resistance in the battery loop at *I* between the points *A* and *B*. The resistance of the galvanometer has been neglected, and it has also been assumed that the electro-motive force and internal resistance of the battery, and the resistances of the various contacts remain constant. While this is not theoretically true, it is found

that by using storage batteries and making the contacts carefully no appreciable error is introduced.

Communication between the two observers, which is necessary to secure a simultaneous observation, is secured by a telephone, the transmitter and receiver being attached to the telescope in proper positions for the mouth and ear while the eye is employed in aligning the telescope. An electric bell attachment is also provided, so that when the vessel is rolling "snap shots" may be taken; that is, the observer at *A* when he has aligned his telescope on the object will close the bell circuit at his end, then when *B* has his instrument correctly aligned, he will touch the button and both bells will ring, and the telescopes will rest until a reading has been made of the galvanometer, which is placed at any convenient point, like the chart room, or conning tower. The range being known and communicated to the person in charge of the gun, he can at once give the piece the proper elevation.

Trials have been made of the instrument during the past two years on vessels of the United States, French, Italian and Russian navies. These tests have been carefully conducted under the authority of the respective governments, and the results as reported by the officers in charge have demonstrated that the invention is a very great improvement over the methods formerly in use. The first installation was made upon the U. S. S. *Chicago*, and observations were made from that vessel while moored at the wharf at the New York Navy Yard upon prominent objects in the harbor. Two base lines were used, in length, 200 feet and 44 feet, respectively. The distances measured ranged from 940 to 1,325 yards. The mean of errors with the long base line was 0·6 per cent., and with the short base line 1·9 per cent.

Better instruments were installed on the U. S. S. *Baltimore*, and after a six months' trial at sea an official report was made, which showed very satisfactory results. The base line was ninety-three yards long. The telescopes were screwed down on the centre line of the deck. One galvanometer was placed in the conning tower and the other on

the bridge. The telescopes were adjusted by sighting them on the moon, which being practically at an infinite distance laid them parallel, and the galvanometer stood at zero. Trials were made in various harbors of Europe while the vessel was lying at single anchor, rolling and swinging; the observations were compared with the positions plotted on the chart, and the variations from the true distance were found to be slight. In the harbor of Spezia, Italy, with the ship lying directly between a fort and a lighthouse, observations were made upon both objects. By adding together the distance from the ship to each object by range finder, and comparing the sum with the distance between the objects as shown by the chart, the error of the range finder was shown, and the uncertain position of the ship as it swung at anchor was eliminated. The mean of twelve observations to the fort and seven to the lighthouse was taken, and showed an error of only one-half per cent.

Good results were obtained at target practice off the harbor of Villa Franche. There was a gentle breeze and the ship rolled slightly. Two targets were shot away and the floating barrels and planks of which they were formed were frequently hit. But few wild shots were made, and the first shots were about as good as the last. The rolling of the ship did not materially affect the reading of the needle, and the shock of the discharge had no effect upon the instruments. The Board reported that reliable results were obtained within three per cent. in ranges less than 5,000 yards, and that the observations may be made by any two sailors after a little instruction and practice.

This result is practically the same as that obtained on the ship *Formidable* of the French Navy which showed the average of errors in distances between 800 and 4,500 yards to be about three per cent. The official report of the trial states, however, that the errors are due more to inaccurate observations than to the electrical apparatus; greater accuracy might be obtained also by using a galvanometer with a larger scale, so that closer readings could be made.

A commission of five officers of the Italian Navy made trials of the range finder on board the ironclad *Terribile*, under

all possible conditions at sea in the Mediterranean nea Spezia, Italy. The official report states that the instrumen has positive merit and can render most useful service, being ingenious, practical and of most easy management.

The results obtained in this practical way have established the value of the invention, and other vessels of the United States Navy are now being equipped with the Fiske range finder. It is not alone, however, in marine warfare that the instrument may be used to advantage; it has even greater capabilities when used in fortifications commanding harbors and adjacent waters. There base lines of any desirable length can be secured, and observers may be sta

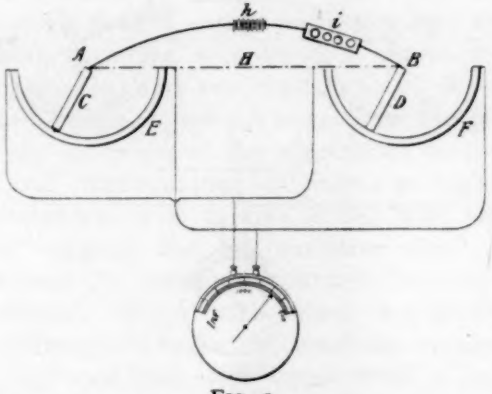

FIG. 2.

tioned at the most advantageous points, while each group of guns may be directed by the officer in command, who may concentrate the fire of them all upon a single ship, or fire at different ships, as his judgment may dictate.

For this service the position finder is equally necessary with the range finder. This instrument shows the direc tion or bearing of the object, which though visible from the ends of the base line, may be concealed by smoke or fog from the gunners. In principle the instruments are the same. A second galvanometer is connected to the same conducting arcs as the range finder, but differently, the connections being so made that the deflections of the needle depend upon the sum of the angles through which the telescopes

are moved from the zero position. The deflection of the needle shows the angle which a line joining the object aimed at and the centre of the base line makes with the base line. If, therefore, the guns are placed near the centre of the base line, they can be directed upon the target, even though the latter is not visible from the guns.

Fig. 2 illustrates the method of connecting the galvanometer for the range finder, *Fig. 3* the connections for the position finder.

In view of the ingenuity displayed in the invention and the great advance it makes in securing a more effective ser

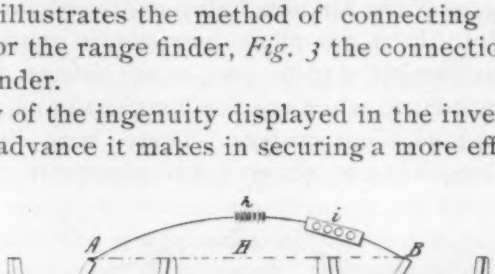

FIG. 3.

vice of heavy ordnance, your committee feel justified in recommending the award of the Elliott Cresson Gold Medal to the inventor.

E. A. SCOTT, *Chairman*, CARL HERING,
CLAYTON W. PIKE, L. F. RONDINELLA,
C. BILLBERG.

Adopted, June 1, 1892.

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

ECONOMICS OF "AUTOMATIC" ENGINES.

By R. H. Thurston.

The "automatic" steam engine is a form which, though a generation old, has come into very general use only within a few years, and mainly since the demands of electric lighting have been so exacting in the matter of regulation. In earlier days, a variation in speed of five per cent. or more from the mean, in many applications of steam-power, was perfectly admissible; and even in the most exigent of work, that of cotton mills making "fine goods, two per cent. variation was thought about the limit of practical attainment and very satisfactory. It is now considered that a range of one per cent. from the mean is too great for the purposes of the electrician, and, so far has invention and improvement extended, it is possible to secure a guarantee, from makers of the later forms of the "automatic" engine, that no variation shall take place though the load be thrown off entirely and at once completely restored; while, with some constructions, it is actually practicable to make the machine assume a higher speed with full load than with none. This is an incidental result of the attempt to meet the requirements of modern engineering; which requirements compel a complete revolution in the type of engine formerly most familiar to us.

The greater part of the machinery to be driven by these engines, as constructed by the electrician and engineer, calls for a small amount of power and a very high speed of rotation. The armatures of standard forms of dynamo-electric machines ordinarily range from speeds of 1,000 to 3,000 revolutions per minute; though special constructions are brought down to a fraction of these figures. The power is from ten to forty or fifty horse-power in common distributions and up to as high as 250 for the largest single dynamos; although, often, the dynamos may be so grouped that from 500 to 1,500 horse-power may be taken from one

engine. It is not yet possible, in all cases, to determine whether a large single engine or several smaller machines of similar aggregate power is best; but the demand for the small engine of from twenty-five to 100 horse-power is enormously great, and the manufacture of this class of engine has been immensely stimulated by the comparatively recent developments of systems of production and of distribution of electric energy. These machines are commonly of the class here denominated "automatic," are 'high-speed" engines of a modern and special type, and are characterized by a "positive" valve-gear, as distinguished from the older and more familiar forms of "trip cut-off" or detachable gear, with regulation by a governor which determines the point of cut-off by, usually, shifting an eccentric, as years ago employed by Hartnell and by Hoadley, and this engine is built to operate at a speed seldom less than 200 revolutions a minute, and often above 300. The positive motion, as a valve system, and the shaft-governor, are necessary consequences of the demand for high speed of rotation and nice regulation; the latter being, in fact, a more essential matter than the former, and one which has compelled many modifications of the details of construction of the older forms of engine to secure satisfactory uniformity of motion. The characteristics and the essentials of each type are now so familiar to all that it is unnecessary for present purposes to describe them in detail. An "automatic" engine has come to be defined as one in which these methods of construction have been adopted and which, having a positive valve-motion and firmly connected governor, adjusts its power to its load automatically through the latter. The definition logically applies quite as well to the Corliss and Greene and similar detachable systems of valve-gear; but convention seems to confine it to the later high-speed engine.

The modern automatic engine, at its high speed of rotation, brings into play the forces of inertia to an extent never observed in the older machine, and its design must usually be modified somewhat to insure smooth working by the introduction of compression and counter-balancing to a

correspondingly greater extent, and with much greater care than formerly. This means increased clearances, as compared with the other type, and often heavier running parts, adjusted as to weight in the manner first practised by Porter, as well as the long familiar counter-balancing. The Porter system gives more perfect adjustment of pressure on the journals. and the last gives insurance against shake of the engine, as a whole, on its foundations. These dynamic actions and adjustments have been the subject of many and extended investigations, both mathematical and experimental, and the result has been admirable success in the improvement of the standard engine of the time, in this respect, and beautifully smooth running, where intelligence and experience have conspired in design and construction. It is proposed to consider the economics of such an engine, assuming it to represent the best contemporary practice in these respects, and to be ready for operation under at least ordinarily favorable conditions. The exact expenditure of heat, steam and fuel under specified representative conditions of this case, including steam-pressure, back-pressure, ratio of expansion, and boiler-efficiencies, can be computed for the thermo-dynamic, ideal case; and, knowing the magnitude and conditions of physical operation of the engine, friction included, its wastes of energy, whether thermal or dynamic, can be very closely obtained by computation, and these wastes being added to the total thermo-dynamic expenditure, the gross outlay of energy becomes known and the economical problem can be solved. The following is an illustration of these facts, as determined for an "automatic" simple condensing engine, rated at ten to fifteen horse-power; having a cylinder six inches in diameter and eight inches stroke of piston, its speed 280 revolutions a minute, and the machine proportioned for a steam-pressure of 100 pounds, though strong enough to be driven, if necessary, with a much higher, perhaps, with little risk, at fifty per cent. higher pressure. Compression is complete and leakage insensible.

It is proposed to compute the demand for heat and steam for the purposes of designer and purchaser, on the assump-

tion of the date given below, the conditions as to waste being substantially those illustrated in the Sandy Hook experiments of 1884. Pressures are taken from seventy-five to 155 pounds per square inch above the atmosphere; ratios of expansion from 1·6 to 16, and the engine as speeded at 280. External wastes of heat are assumed to average 0·5 b. t. u. per square foot of external surface and per degree range of temperature from atmospheric—here taken as 100° F. Internal wastes are taken as aggregating, as a fraction of the total steam supplied,

$$w = a / d. \sqrt{r\,n}$$

where the coëfficient $a = 4$ in the case assumed to be fairly represented of that here considered; d is the diameter of cylinder in inches, r the ratio of expansion, and n the number of revolutions per *second*. This simple expression will probably answer present purposes, in the absence of a more exact and better established one. Friction wastes are taken as found for short cut-offs, efficiency of the engine as a machine being assumed at 0·85. Better work than this can be and should be done. J is taken as 778. The following are the assumed data:

DATA.

$p_1 =$	75	95	115	135	155′
$p_3 =$	5	5	5	5	5
$r =$	1·6	2	4	8	16
$c = \frac{1}{r} =$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$

Pressures are here measured from absolute zero.

The work per cubic foot of steam is here computed by the familiar expressions of Rankine:

$$U D_1 = J D_1 \left[T_1 - T_2 \left(1 - \log_e \frac{T_1}{T} \right) \right] - \frac{T_1 - T_2}{T_1} l_1 - r(p_2 - p_3)$$

and

$$p_2 = U D_1 / r.*$$

The results of these computations, as made and checked

* *Rankine's Prime Movers; Thurston's Manual*, p. 398.

r	Cut-off.	Pressure, Pounds per Square Inch.	Temperature Absolute. T_1.	Density of Steam.	Latent Heat, Foot-Pounds.	Terminal Pressure, Pounds per sq. in.	Terminal Pressure, Pounds per sq. ft.	Temperature. T_2.	Indicated Power.	Steam per I.H.P. per Hour (Ideal) W.	Internal Waste Coëffic. $\frac{a}{d}\sqrt{\frac{r}{n}}$	Internal Waste, Pounds per I.H.P. and per Hour.	External Waste, Pounds per I.H.P. and per Hour.	Total Waste, Pounds per I.H.P. and per Hour.	Total Consumption, Pounds per I.H.P. and per Hour.	Same per D.H.P.
16	1–16	75	768·6	·175622	110,437	3·22	463·7	605·4	3·100	*15·85*	1·234	19·56	3·30	22·86	38·71	45·54
8	⅛	75	768·6	·175622	110,437	7·08	1,020	638·6	6·42	*15·32*	·87287	13·17	1.50	14·93	*30·25*	*35·58*
4	¼	75	768·6	·175622	110,437	15·55	2,239	676	11·77	*16·72*	·61720	10·32	·847	11·167	*27·887*	*32·80*
2·7	3/8	75	768·6	·175622	110,437	24·29	3,498	699·7	14·97	*18·48*	·50710	9·88	·666	10·546	*30·026*	*35·32*
2	½	75	768·6	·175622	110,437	34·15	4,918	719	17·85	*21·44*	·43650	9·71	·555	10·265	*32·51*	*38·24*
1·6	⅝	75	768·6	·175622	110,437	44·00	6,336	734·2	19·90	*24·76*	·3900	9·66	·502	10·162	*34·92*	*41·08*
16	1–16	95	785·1	·219430	151,336	4·08	588	615·0	4·83	*12·74*	1·234	15·73	1·663	17·393	30·133	35·45
8	⅛	95	785·1	·219430	151,336	8·97	1,292	649·4	9·31	*13·21*	·87287	11·53	·969	12·409	*25·71*	*30·24*
4	¼	95	785·1	·219430	151,336	19·70	2,837	688·4	15·97	*15·42*	·61720	9·09	·366	9·656	*25·076*	*29·50*
2·7	3/8	95	785·1	·219430	151,336	30·77	4,431	713	20·58	*17·72*	·50710	8·99	·428	9·418	*27·14*	*31·93*
2	½	95	785·1	·219430	151,336	43·26	6,229	733·1	24·20	*20·34*	·43650	8·88	·375	9·255	*29·595*	*34·81*
1·6	⅝	95	785·1	·219430	151,336	55·72	8,024	749	26·62	*23·11*	·3900	9·02	·333	9·353	*32·46*	*38·19*
16	1–16	115	799·1	·262732	179,142	4·94	711·8	623·0	6·18	*11·91*	1·234	14·70	1·360	16·060	27·97	32·91
8	⅛	115	799·1	·262732	179,142	10·86	1,564	658·4	11·62	*12·68*	·87287	11·07	·755	11·825	*24·55*	*28·82*
4	¼	115	799·1	·262732	179,142	23·84	3,433	698·6	19·68	*14·97*	·61720	9·24	·415	9·655	*26·48*	*28·97*
2·7	3/8	115	799·1	·262732	179,142	37·25	5,364	724	25·28	*17·35*	·50710	8·80	·331	9·131	*28·836*	*31·15*
2	½	115	799·1	·262732	179,142	52·36	7,540	745	29·64	*19·88*	·43650	8·68	·276	8·956	*3*	*33·92*
1·6	⅝	115	799·1	·262732	179,142	67·46	9,714	761·5	32·60	*22·60*	·3900	8·82	·251	9·071	*31·67*	*37·26*
16	1–16	135	811·2	·305659	206,286	5·8	835·6	630·0	7·534	*11·38*	1·234	14·05	1·043	15·093	26·473	31·14
8	⅛	135	811·2	·305659	206,286	12·75	1,836	666·2	13·91	*12·32*	·87287	10·75	·504	11·314	*23·63*	*27·80*
4	¼	135	811·2	·305659	206,286	27·99	4,031	707·6	23·37	*14·67*	·61720	9·05	·344	9·394	*24·06*	*28·30*
2·7	3/8	135	811·2	·305659	206,286	43·73	6,297	733·9	30·00	*16·96*	·50710	8·60	·263	8·863	*25·82*	*30·37*
2	½	135	811·2	·305659	206,286	61·47	8,852	755·3	35.00	*19·54*	·43650	8·53	·226	8·756	*28·29*	*33·28*
1·6	⅝	135	811·2	·305659	206,286	79·19	11,403	772·4	38·50	*22·25*	·3900	8·68	·208	8·888	*31·13*	*36·62*
16	1–16	155	822	·348265	232,738	6·66	959·4	635·80	8·89	*10·98*	1·234	13·55	·836	14·336	25· 6	28·84
8	⅛	155	822	·348265	232,718	14·63	2,106	673·0	16·20	*12·05*	·87287	10·52	·462	10·982	*23·03*	*27·09*
4	¼	155	822	·348265	232,738	32·14	4,628	715·3	27·00	*14·41*	·61720	8·29	·274	9·164	*23·57*	*27·73*
2·7	3/8	155	822	·348265	232,738	50·2	7,223	742·3	34·58	*16·72*	·50710	8·48	·213	8·693	*25·41*	*29·89*
2	½	155	822	·348265	232,738	7· ·58	10,163	764·5	40·50	*19·28*	·43650	8·41	·182	8·592	*27·87*	*32·74*
1·6	⅝	155	822	·348265	232,738	90·92	13,092	782	44·48	*21.95*	·3900	8·57	·164	8·344	*30·68*	*36·26*

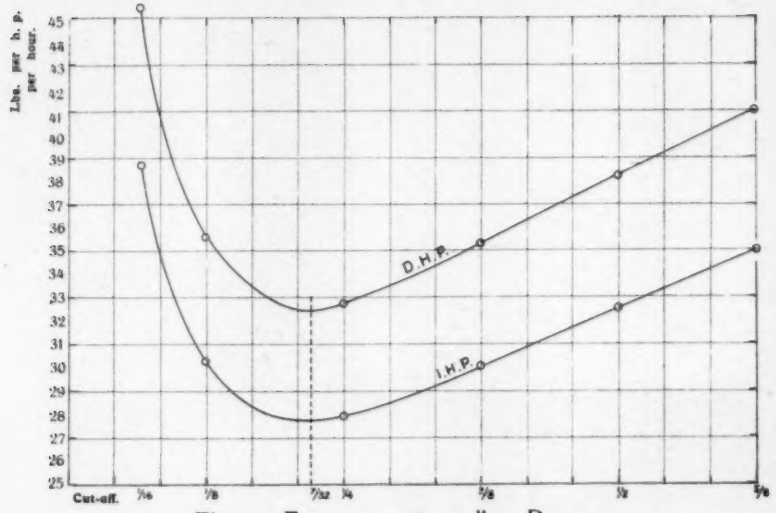

Fig. 1, Economy at 75 lbs. Pressure.

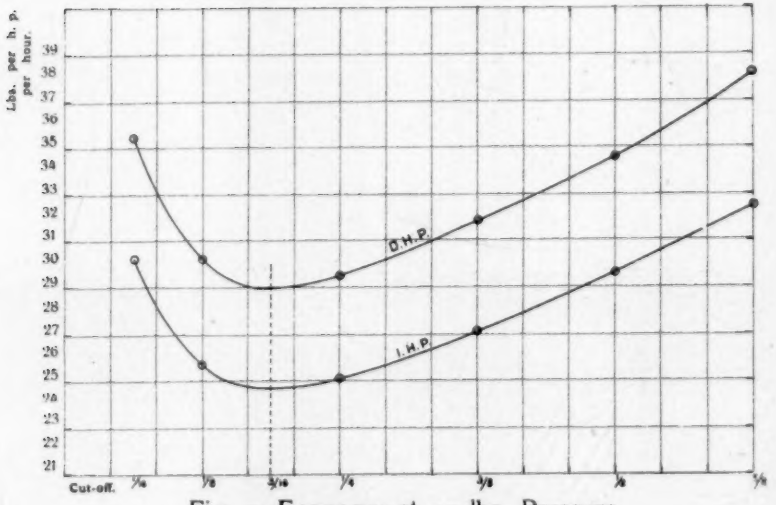

Fig. 2, Economy at 95 lbs. Pressure.

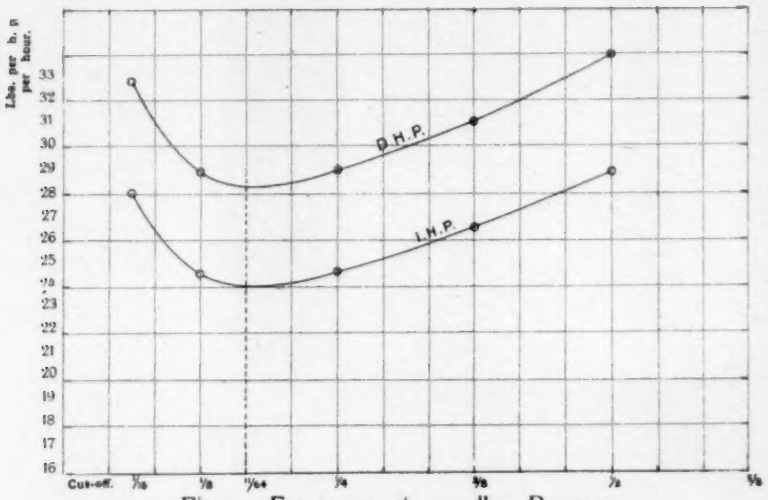

Fig. 3, Economy at 115 lbs. Pressure.

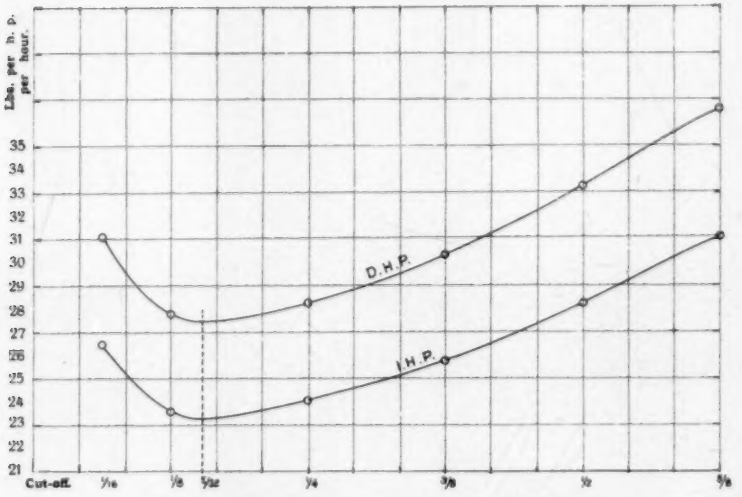

Fig. 4, Economy at 135 lbs. Pressure.

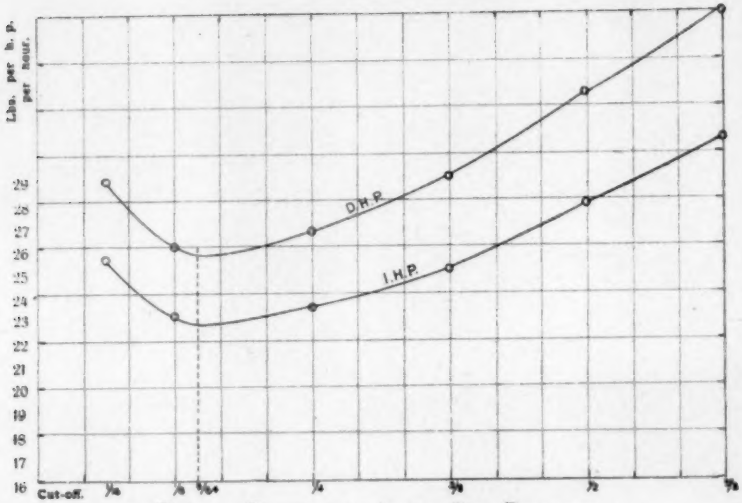

Fig. 5, Economy at 155 lbs. Pressure.

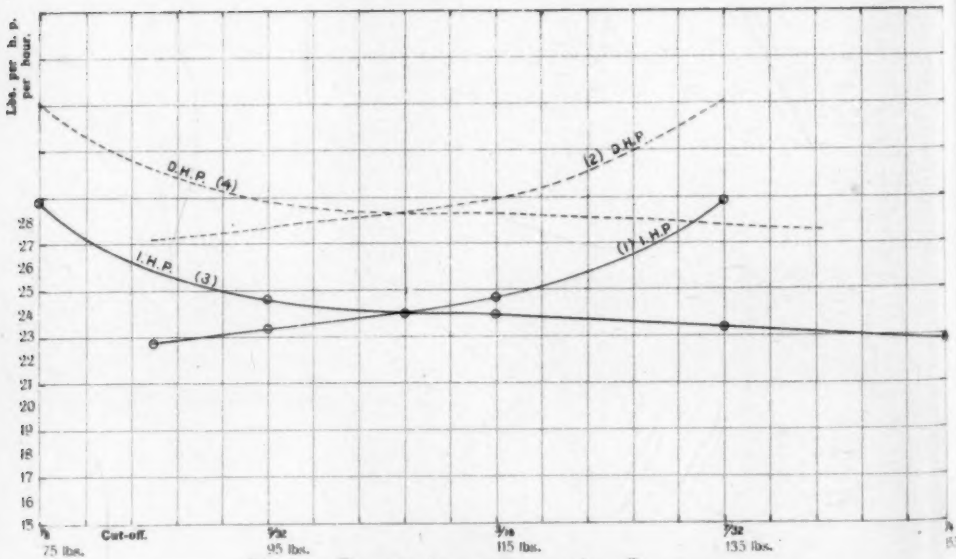

Fig. 6, Economies with varying Pressures.

by Messrs. C. B. Auel, A. R. Henry and F. P. Ide, following the methods prescribed by the writer, are presented in the accompanying table.

An examination of the figures here collected will show in a most interesting manner the gradual variation of steam consumption with change of expansion at each pressure and a comparison of the figure for the several pressures wil illustrate the interesting modifications of result due to variations of expansion with pressures, and the differences in the location of the best points of cut-off for these pressures. These instructive comparisons are best made by the construction of curves, of which the coördinates are, for each pressure, weights of steam demanded per horse-powe and per hour at stated ratios of expansion. Such curve have been drawn by the computers for the present case, and are illustrated in the accompanying plates. It is seen that at the lowest pressure, 75 pounds, maximum economy o steam and fuel is attained at a cut-off very near $\frac{7}{32}$, or a ratio of expansion of about 4·5, when the dynamo-metric power is taken, or at about a cut-off of 0·2 and $r = 5$, on the basis of indicated power. These figures become about 3·16 and 5 at 95 pounds, $\frac{11}{64}$ and 6 at 115, $\frac{5}{32}$ and 6·4 at 135, and $\frac{9}{64}$ and 7 when the pressure becomes 155 absolute, or 140 pounds by gauge.

This gradual shifting of the ratio of expansion giving highest economy of fuel and of steam is better illustrated in the last set of curves in which two exhibit the variation of this point of cut-off with varying pressures, while the other pair show the progressive gain in economy of fuel and of steam in a similar manner; the numerical values of the former quantities increasing, and the latter decreasing with rising steam-pressure. The weight of steam consumed is not far, at best, from

$$w = 250 / \sqrt{p}$$

pounds of steam per hour per indicated horse-power, when working under best conditions, and the best ratio of expansion, on the same basis, is about

$$r = 0{\cdot}5 \sqrt{p}$$

The conditions here assumed may be taken as fairly representative of good practice with such an engine. Where leakage occurs, or when compression is incomplete and the clearances thus become sources of additional wastes, these figures may be much exceeded. Experiments with an engine of such dimensions and proportions as are here assumed, as made under the eye of the writer, have given internal wastes through these faults of construction and of operation, amounting to three times that here found, and bring the expenditures of steam and fuel up much higher figures. Those here obtained, however, correspond with working conditions which can probably always, with care, be obtained in the actual case, and may serve as a guide in the designing or the selection of such engines for use. Larger engines will be less subject to such wastes, and the margin between the ideal case and the actual, may be thus reduced approximately in proportion to increasing size of engine. The economically desirable ratio of expansion and point of cut-off, however, is always somewhat less than that found to give lowest expenditure of steam and fuel, since every item of cost in the construction of the engine involves a corresponding annual charge thereafter, and a compromise between increasing annual expense on this count, and decreasing cost of fuel must be made to secure the best results.

The commercially desirable ratio of expansion is always less than that giving maximum duty; but the margin between the two depends greatly upon the relative costs of construction and of operation of engine and boiler and cost of fuel. Methods of exact computation are becoming developed and approximate methods are well-known.* In general, at the commercial centres, the ratio to be adopted in designing will not be far from two-thirds that here found to give best effect for the ideal case, twenty per cent. lower than is shown on the diagrams for the actual case, and still lower where it is sought to make the most out of an engine already set and in operation.

---

* *Manual of Steam Engines*, Vol. I, Chapter VII.

The mean effective pressure here found is seen to be not far from

$$p_2 = 6 \sqrt{p_1}$$

and the pressure to be adopted by the designer for such cases will be greater, perhaps not far from

$$p_1 = 5 \sqrt{p_1} -$$

gauge-pressures being here taken while the power of the engine is seen to be approximately

$$I.\ H.\ P. = 0{\cdot}03\ d^2 \sqrt{p_1}$$

nearly and slowly rising with increasing pressure. Had the wastes of the engine been larger, which is oftener the case than the opposite, the cut-off would be deferred, the ratio of expansion lessened, the mean effective pressure increased and the relative power for a given size of engine increased, since in such cases, the gain by reduction of wastes more than offsets the thermo-dynamic gain by the reverse process of increasing the ratio of expansion. The figures here obtained may be taken as representing the limit of expansion in the case of the best makes of automatic engine, under best conditions of operation. In the usual case, a lower ratio of expansion and larger mean pressure will be desirable.

THE AËRATED FUEL COMPANY'S SYSTEM OF BURNING OIL BY COMPRESSED AIR.

BY W. S. COLLINS.

[*Abstract of a paper read at the stated meeting of the Institute, held June 15, 1892.*]

JOS. M. WILSON, President, in the chair.

MR. COLLINS: The advantages of oil as fuel seem to have occurred to those engaged in handling the article, in this country, very soon after its discovery in Western Pennsylvania, as there are accounts of its use, in a crude way, under boilers more than twenty-five years ago. The number of plans devised for burning this liquid fuel, and the number of patents issued for them, are very large; but it is only within the last seven or eight years that a method has been devised for burning oil in a way to meet all the requirements of the different kinds of fire required in various lines of mechanical work. What are these requirements? We shall not attempt to describe each kind of fire in detail, but generally the requirements of a perfect oil fire are:

(1) That it shall be capable of giving the varying degrees of heat required in each line of work, and be subject at all times to the instant control of the workman.

(2) That it shall produce complete combustion, leaving no smoke or smell.

(3) That it shall be entirely free from sulphur or other impurities.

(4) That it shall be capable of being made a more or less oxidizing flame.

(5) That it shall be as safe as, if not safer than, a coal or wood fire.

(6) Last, though not least, that it shall be at least as cheap, in cost of fuel, as coal or wood.

The experiments which have been made to obtain these results may be divided into three general classes: In one

a retort or system of retorts is employed to convert the oil into gas before it is burned. This plan demands, in nearly every instance, the use of more or less complicated apparatus, or necessitates a special arrangement of the fire box, which unfits it for service in the event of the stoppage of the gas generating device.

Another class uses steam, or steam and air, to atomize the oil. The objection to every steam-jet burner is that it cannot be successfully used in all kinds of work, as it is difficult to get the highest degrees of heat when steam is mixed with the oil, and the heat from a steam-jet burner cannot be perfectly regulated nor made subject to instant control.

The third class relies upon air alone to atomize the oil. This is done in two ways: One is by spraying the oil, which is allowed to run out on the tines of a fork in the burner, by means of air under six or eight ounces pressure from a fan blower.

The chief objections to this system are:

(1) That it is of necessity a gravity system; that is, that the oil must be at some point a little higher than at the point of combustion, in order to enable it to flow to the burner, as six or eight ounces pressure from a fan blower is not sufficient to lift the oil to the burner, as is done where air under ten or fifteen pounds pressure is applied to it.

(2) That it requires more power to run a fan blower, to spray a given amount of oil, than it does to run an air compressor to spray the same amount.

(3) That a fan-blast burner, as has been shown by repeated independent tests, consumes nearly one-third more oil for a given amount of work than the compressed air burners.

The other air-spraying system is to subject the oil to sufficient pressure, to lift it from the storage tank, placed below the point of combustion, to the tip of the burners, where it is met by the air under the same pressure and driven into the fire, through an orifice, varying from one-thirty-second of an inch to five-eighths of an inch in diameter, in a fine spray. It is this compressed air system,

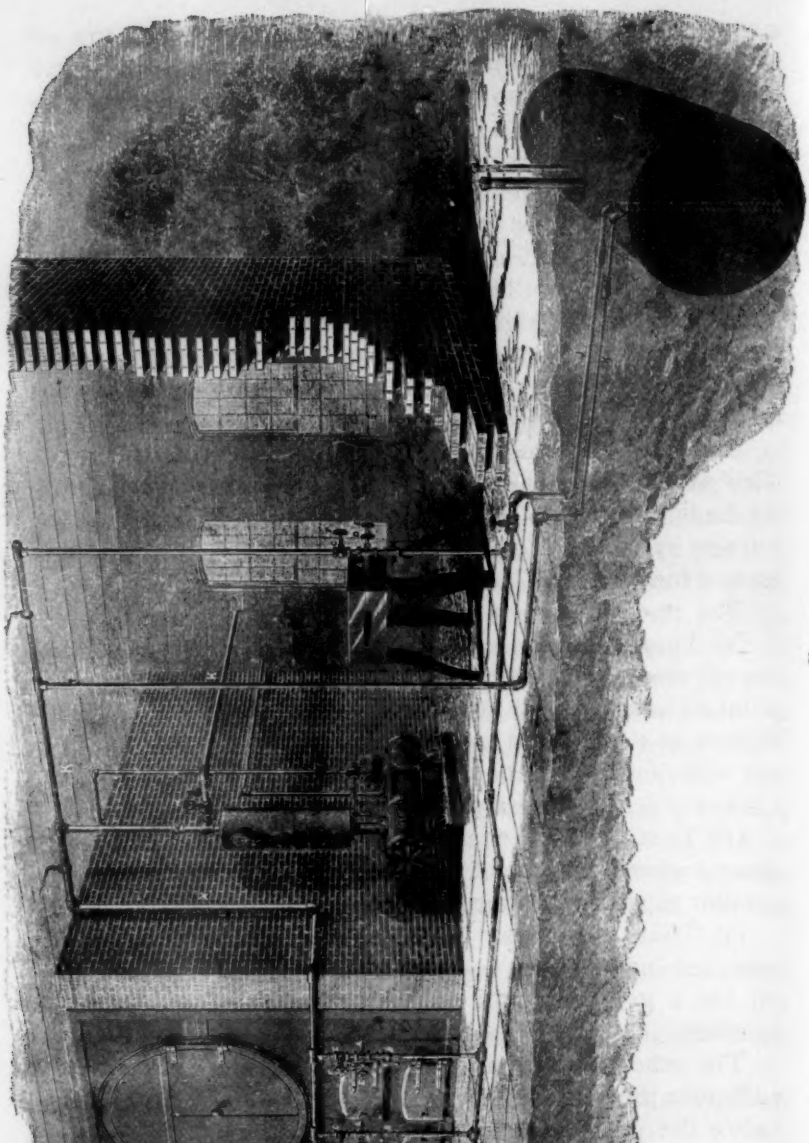

FIG. 1.

devised and patented about seven or eight years ago, and since then gradually perfected by James H. Bullard, of Springfield, Mass., and now owned by the Aërated Fuel Company, that we propose to describe more fully in this paper.

The diagram (*Fig. 1*), here shown, represents a small plant arranged according to this system. *G G* is an air compressor, which may be called the heart or life of the system. The compressor may be run either by a belt from shafting or better by steam direct from the boiler, as shown in the diagram. *Fig. 2* shows a duplex steam-actuated air compressor. The air, compressed usually to about fifteen pounds to the square inch, passes into the air receiver shown on top of the compressor. This equalizes the pressure and eliminates the pulsations of the air compressor. The governor on the air compressor allows no more steam to be taken than is needed for the number of burners in use at the pressure required. From the receiver the air passes through the main air pipe *K*, down to the tank containing the oil, which is always placed below the level of any of the fires. As this tank is made air tight, the pressure of the air on the surface of the oil forces it through the main oil pipe *J* to the only outlet which it can find, namely, at the tip of each burner *A*, on the small oil pipes extending upward from the main pipe *J* to each burner. It will be noted that the main air pipe *K*, besides being connected with the oil tank, extends by small branches to the top of each burner *A*, and meets the oil which is conveyed through a small pipe in the interior of the burner to a point very near its tip. Exterior and interior views of the burner are shown in *Figs. 3* and *4*. The air in the burner surrounds the small oil pipe so that when it meets the oil at the tip of the burner it strikes the oil on all sides and mingles with it, thus forcing the oil from the tip of the burner in a fine spray. This spray, looking like a jet of water, extends four or five inches from the tip of the burner, which is always placed about one inch from an orifice in the furnace through which the spray of oil and air is driven. At the distance of four or five inches from the tip of the burner the oil, when lighted, bursts into a flame,

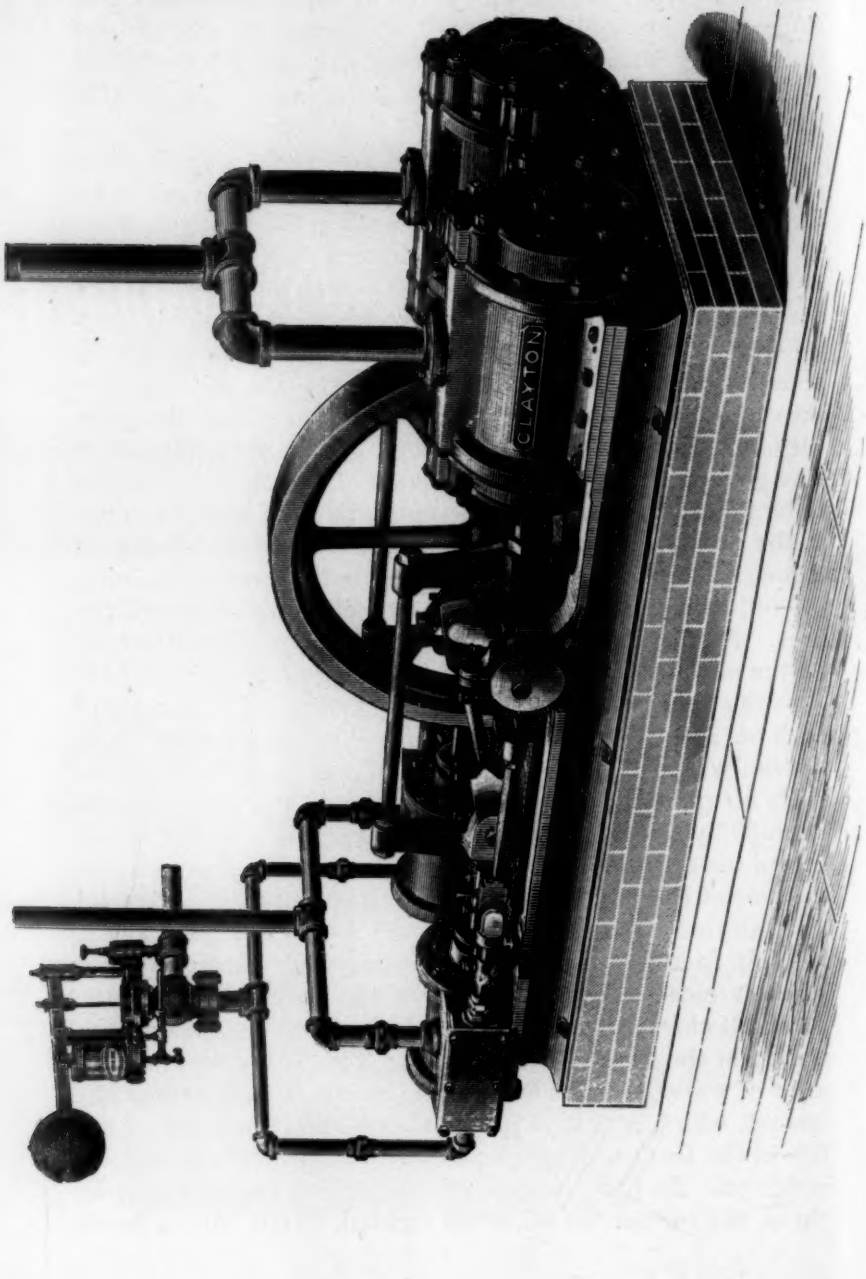

FIG. 2.

which may be varied all the way from a yellow, and if desired, a smoky flame to a clear white flame as bright as an electric light, by governing the proportion of oil and air by means of the cock at the butt of the burner. Its length, also, may be varied from fifteen to sixty inches, or more. The pressure under which the oil is forced into the fire varies all the way from one-half pound to about twenty pounds to the square inch, according as the kind of fire required for the work varies from a gentle heat through different degrees of red heat up to an intense white heat. In this way the Aërated Fuel Company's system meets the first requirement which we have stated, namely, that the fire shall be capable of giving the varying degrees of heat required in each line of work.

Before passing on to notice the other points, we may add, as a further description, that where the system is used on a large scale, it is usually desirable to employ an automatic oil pump and tank (shown in *Fig. 5*, as built specially for this system by the Hall Steam Pump Company), although this is not necessary. From the main storage tank in the ground the oil is raised in small quantity by this steam or belt-actuated oil pump, which is automatically controlled by a float valve in the small tank under the pump. When the oil reaches a certain level in this tank, the pump stops until enough oil has been used by the burners to lower the oil in the tank sufficiently to start the pump again. In practice, the oil pump, in large plants, works continuously, though slowly.

We have already indicated, in general, that the fire is at all times subject to the instant control of the workman by turning the cock at the butt of the burner. This is used where a slight variation only is required. When it is desired to alter the proportion of the air and oil to a greater degree, this is done by partly closing either the air valve in the pipe above the burner or the oil valve in the pipe below. The air pipe is spoken of as being above the burner, but the burner may equally well be placed with its air and oil connections horizontally, and the air pipe be carried down and placed under the floor, as the oil pipe should always be.

In this case the burner is situated at the centre of an inverted ∩.

Our second point, that an oil burner should produce complete combustion leaving neither smoke nor smell, is secured in the Aërated Fuel Company's system, by supplying at the tip of each burner exactly the proportion of oil and air requisite to give perfect combustion. Some free air is also taken in at the opening in the wall of the furnace through which the oil spray enters the box. This opening

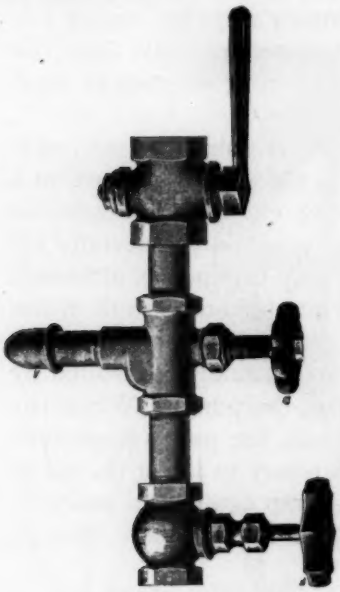

FIG. 3.

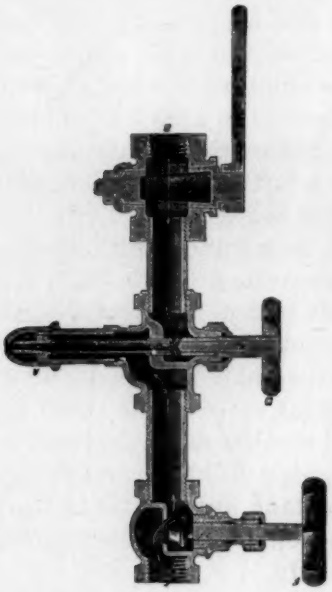

FIG. 4.

varies from one to four inches in diameter. Where the system is used for generating steam, or similar work, requiring a large amount of free air, this is admitted through the ash-pit doors, or better from the rear of the fire box through a special flue under the floor, so that the air passing through this flue becomes heated before it enters the fire box.

A great deal of thought has been expended by the managers of the Aërated Fuel Company, to meet the fifth requirement, namely, to make their system not only as safe

as a coal or wood fire, but even safer, and they feel that they have accomplished this, both from the testimony of the insurance companies and of users of their system, and also from the fact that the system is so arranged that if the air pressure stops at any time from the breaking of a steam or air pipe, the fires are instantly extinguished, and the oil in the pipes runs back to the storage tank. Where an automatic oil pump and tank is used, the oil pump stops as soon

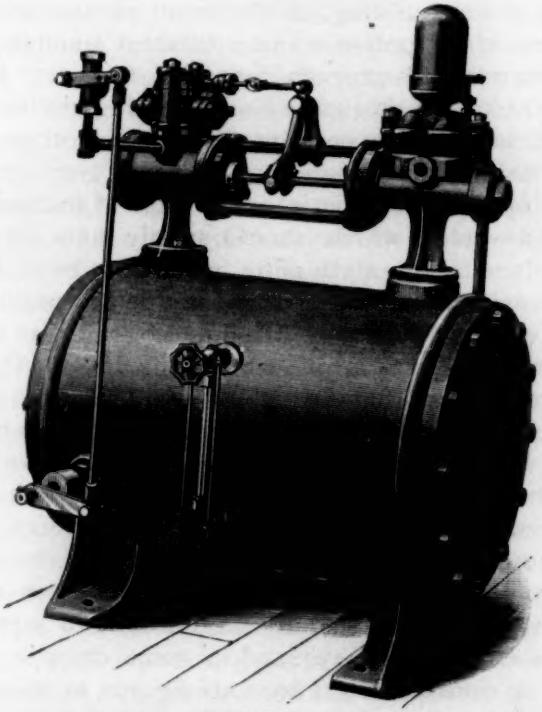

FIG. 5.

as the air pressure stops, because the oil, ceasing to be forced into the fires, rises in the tank under the pump and shuts off the steam from this pump so that only ten or twenty gallons is above ground at any time, and this is stored in the iron tank under the oil pump. The only possible way in which fire can occur with this system, is by some workman carelessly turning on his oil and air and omitting to light the

fire, thus causing a fine vapor of oil to gather in the fire box. If enough of this is allowed to accumulate before it is lighted, an explosion is pretty sure to follow. But all the fires can be instantly extinguished by the engineer, or by any one else, shutting off the steam from the air compressor, and each fire may be shut off by its separate oil and air cocks without affecting any other fire.

A special feature of this company's system is that fires can be obtained at various levels, even extending to different floors of the building, on the same plant, and a different amount of air pressure and a different amount of heat can be maintained at each forge or furnace. In some places furnaces on the same line of piping are using two pounds of air pressure per square inch, and others beside them are using fifteen pounds.

While our first five points are of interest to users of oil as a fuel, a system which should supply them all and yet not comply with our sixth point, namely, to be at least no more expensive than coal is, would not be acceptable to the majority of manufacturers. It should be noted in the first place—and this point is one which it is difficult for many persons to realize—that the amount of oil required to equal a ton of coal varies very greatly in different lines of work. In small forgings, and the melting of lead or other soft metals, the amount of oil needed to equal a ton of coal can be reduced by careful handling to about forty gallons, while where a high degree of heat is required, or where the oil is to be burned in a large fire box, as when used for generating steam, the amount of oil needed to equal a ton of coal rises to 80, 100, 150 and in some cases to 175 gallons. It is difficult to get accurate figures, as most manufacturers either do not know, or will not tell, how much oil they use in their work; but from an abundance of reliable data in the company's possession, from users of the system, the great economy of the system is demonstrated beyond peradventure.

It would naturally be supposed that in order to consume completely varying amounts of oil it would be necessary to increase the number of burners largely according to the

demands of the work, but with the Aërated Fuel Company's system the regulation is so perfect that the amount of oil which can be thrown through the same burner varies through a range of from 1 to 400, perfect combustion being obtainable with whatever amount of oil is used. Of course, a different sized tip is used for various lines of work where the amount of oil needed varies greatly, but otherwise the only object in multiplying burners is to distribute the heat properly through a large forge or furnace.

It is claimed, by the advocates of the various processes for burning oil with steam, that the component gases obtained by superheating and decomposing the steam give additional heat. It is no doubt true that heat is obtained by burning these gases. But the advocates of mixing steam with oil for fuel purposes seem to forget that to decompose the steam, which they throw in with the oil, requires a certain portion of the carbon contained in the oil which is the chief heat-giving factor; so that the extra heat obtained from burning the steam gases is at the expense of part of the heat contained in the oil. In other words, this process amounts to what is called "taking money out of one pocket and putting it into the other." Beside this objection, steam-jet burners require to be fed by gravity and hence are not perfectly safe. A careful test made with one of the best and most largely used of these burners, by the Farr Alpaca Company, of Holyoke, Mass., shows that it takes nearly six per cent. of all the steam made by the boilers to spray the oil to generate this steam, whereas the amount of steam required to run an air compressor for spraying oil by the Aërated Fuel Company's system for this purpose was found to be less than two per cent. of the total amount produced by the boilers. Moreover, the steam so used in spraying oil is consumed, whereas the steam used to run the air compressor may be used to heat the feed-water or be condensed and used again in the boilers. It should be borne in mind also, that where a steam-jet burner is used for generating steam, the fire varies, for the reason that when the supply of steam is ample and its force on the oil strong, the atomizing is more perfectly done and consequently a greater

amount of steam is generated, but when the steam supply is low, a low fire is obtained. In other words, a steam-jet burner works in exactly the reverse way to what is desired, giving most heat when least needed, and least heat when most needed.

To illustrate the amouut of heat which can be obtained, at a recent test in burning terra-cotta at the New York Architectural Terra-Cotta Works, the Aërated Fuel Company's burners, on a circular kiln about eighteen feet in diameter, were lighted at the same time on Tuesday morning as the coal in a smaller kiln, the fire in each case being started at a low degree of heat and gradually increased in intensity to the end of the test. The kiln burned by the Aërated Fuel Company's system was finished Saturday afternoon, or in about 95 hours, while the one burned with coal was not finished until Sunday afternoon, or in about 120 hours. The actual degree of heat obtained here was not taken, but on the fourth day before the highest heat was reached, an iron rod about one inch in diameter thrust into one of the peep holes was melted to the point where the iron ran from the end of it in just two minutes by the watch. A similar test in Springfield, Mass., showed that a three-inch square iron was heated to a dripping heat in twenty minutes when the forge was hot, or in thirty minutes beginning with a cold forge, using not over three-fifths of a gallon of oil. At the Westman Gas Company's regenerative gas furnace, Hackettstown, N. J., two three-sixteenths-inch tip burners gave a heat of 3,200° by a pyrometer test.

In connection with the foregoing, it may be interesting to quote the analysis of lima oil, which is the kind usually used for fuel, made by Prof. Chas. Mayr, of Springfield.

"By ultimate organic analysis, the oil was found to consist of

	Per Cent.
Hydrogen,	17·10
Carbon,	80·20
Oxygen impurities,	2·70
	100·00

"The specific gravity of the oil at 75° is ·831.
"One cubic foot weighs 51 pounds, 14 ounces.
"One gallon weighs 6½ pounds, very nearly.
"Its theoretical heating capacity per pound is 18450·2 (pounds of water × degrees F.) heat units."

The same authority says:

"A weight of 7·3 pounds per gallon would correspond closely to many of the grades of petroleum; also, 20,000 heat units per pound is not an uncommon value for the theoretical number of heat units contained in a pound of the fuel.

"In order to derive approximate formula representing the cost of petroleum and coal, let us make the following assumptions:

42 Gallons oil,	1 barrel.
1 Gallon oil weighs	7·3 pounds.
1 Pound coal contains	12,000 heat units.
1 Pound oil contains	20,000 heat units.
Per cent of heat in coal transferable to water,	70 per cent.
Per cent. of heat in oil transferable to water,	80 per cent."

In summing up, it may be said that there are about 200 plants using with this system in this country and in several countries of Europe, and that it is doing about fifty different varieties of work. By fifty varieties we mean that the kind of fire varies to this extent; but speaking generally, it is used for all kinds of iron and steel forging, tempering, welding, annealing, etc.; for making tin-plate; in glass works, for glory holes, lears and ovens; for generating steam; for burning lime, cement, terra-cotta, sewer pipe and brick; for heating chemicals and asphalt; for japanning; for oxidizing lead; for heating retorts in gas works; for drying sand, salt, etc.; for singeing cloth; for shrinking ordnance. From the fact that the system is used in so great a variety of work, there seems to be practically no kind of fire for which it cannot be used, the only question being one of economy as compared with coal; for, as before indicated, while the economy is very great in some lines of work, in other lines there is little or no economy. The line to which the Aërated Fuel Company is at present particularly turning

attention is, for generating steam on steamships and particularly on government torpedo boats. The system is already used on steamships in California, where coal is relatively very expensive, with excellent results; and from the fact that the oil can be stored at the lowest possible point in the ship and forced from that point to the fires, and the fact that the pressure maintained on the oil keeps up a steady flow even when the ship is tossing in the waves, and from the fact that it uses less steam for spraying the oil than any other system, it seems particularly adapted for use on steamships where it is necessary to economize room and steam-power to the greatest extent. If the price of crude oil can be maintained at its present figure, or better if it can be reduced slightly, there is every reason to suppose that before many years the use of oil on steamships, espepially those requiring great speed, and hence great steam generating power, will soon become not unfrequent. It is well known that a well-managed oil fire will get from one-third to one-half more horse-power from a boiler than can be obtained with coal unless a constant force draft is maintained on the coal.

Lack of time has prevented speaking of the improved quality and increased quantity of work produced by the fires of the Aërated Fuel Company's system, but testimony on both these points is ample; so that the system seems destined to be still more widely used in the future, as its merits become more generally understood.

PHYSICAL EXERCISE IN HEALTH AND AS A REMEDY.

By J. Madison Taylor, M.D.

[*A lecture delivered before the Franklin Institute, December 7, 1891.*]

[*Concluded from p. 240.*]

The intimate connection between the heart and lungs makes it impossible that one of these organs should be disturbed without the other also. One of the first effects of exercise is, of course, to increase the frequency of the heart beat to quicken the blood current. The quickening of this blood current during exercise is the result of two factors. The peripheral circulation is enhanced by the increased demand by the working muscle for blood. The whole vascular system, too, shares in this expedition. Then there is the added need felt by the organism for the aëration of the blood surcharged by the carbonic acid poison; hence there arises an active determination of the blood to the lungs. The central nervous mechanism is depressed, the centres of activity are inhibited and motor impulses are impared. Death may result from all this, but very rarely, because a stop is put to this continued movement by the causes enumerated. Thereupon, a seasonable time being allowed, recovery takes place; these volatile poisons are eliminated and the balance of power comes round again.

Exercise in Childhood and Youth.—The normal states of the infant are feeding and sleeping. There is little further needed during the first year of life but comfortable, clean surroundings and abundant food at suitable intervals, supplemented by ample rest. Plenty of air should be allowed and not much light. The little one should be left alone as much as possible. In certain foundling asylums abroad, the babies are fed and put into well-ventilated, darkened compartments immediately, and under this system they seem to do best. Distinct harm results from over-much attention, and the excitement which comes from fond parents or curious relatives is one of the most hurtful

influences exerted upon early infancy. Absolute freedom should be allowed to the limbs, and yet it is true that certain savage nations keep their infants in rigid dressings until they are able to make attempts at walking, and among such there result exceedingly find physiques. This custom on the part of these savages may reasonably be a hint to us that enforced rest to the limbs is wiser after all. Then, as the child gives distinct evidence of wishing to be more aggressive in its movements, it will probably be high time to encourage it. At any rate, in the second year full freedom might be allowed, and a good plan is to place the infant upon a soft substance on an even surface, like the floor, and encourage all spontaneous movements, and to supply the simplest kinds of toys. Try few educational measures yet.

With the eruption of the first set of teeth, about the end of the second year, a more varied diet is admissible also a wider range of object lessons, though these should be still of the simplest. At the first plain indication of weariness, the child should be encouraged to sleep. As the motor energies become more plainly manifested, so may they be cautiously aided and abetted. In all this be guided by the greatest caution lest unwise interference be hurtful. Take lessons from experience, especially of the natural promptings of the youngster, and beware of all fine-spun theories of childless philosophers and narrow-minded grandparents. As soon as the child makes definite efforts at standing, reaching out for objects, etc., supply it with harmless toys, especially washable ones, which can be kept chemically clean, as of rubber or metal. Let it exercise its senses: its muscular sense, teaching it dimensions of external objects, its eye in judging of distances and colors, etc., as well as the coördination of its limbs. Let it pull things about and put them into its mouth. All animals wish to taste or put objects to their mouths, because the lips are equipped with the most sensitive nerves, and here it can obtain most accurate impressions. The hands have not yet learned nicety of touch, but by handling blocks, etc., soon accuracy comes.

The eye in the child is a perfect organ, and so, indeed, is the digestive tract, with limitations, of course, as to capacity. Not so, however, the limbs and trunk, which have much to learn and large need for exercise. It is best that the objects which immediately surround it should be of uncomplicated shape and color, such as the dawning comprehension may compass and use for comparison as the individual is brought into contact with more complex ones. Bear in mind that the best human animals come from simplest households, as nearly as possible to nature, whose phenomena offer the best object lessons. Civilized comforts and safeguards are not to be despised, but these should not offer elements for confusion. A child is best left much alone. Avoid artificial constraints. When wearied out with the joyous spontaneous movements, which quicken its circulation and expand its lungs, and when feasted with slow contemplation of surrounding objects, it should be able to lie down comfortably and sleep.

By and by the bewilderment of early impressions will be replaced by a growing confidence in the maturing powers and values of surrounding objects. All childhood should be passed in a series of simple object lessons. Some small encouragement is very well, but no distinct teacher of any kind is needed until the motive powers are well established and a fair stock of intelligence has been acquired by its own unaided mental digestion.

When fully able to cruise about the room or garden it may do so, clambering up and tumbling down. So shall it acquire knowledge of its own powers and limitations, so learn to save its own head from injuries and gleefully secure coveted objects. Thus, little by little, stores of information may be acquired, a possession which is all its own, because come at through abundant slow contemplation in its own time and manner and by its own unaided faculties. These powers, too, grow by what they feed on. Selection is thus exercised; eye and hand and leg are brought to the fulness of their strength, and the highest human faculty—judgment—is soon or late acquired. In the mere bodily activities a

healthy child may be trusted to do enough and not too much. If urged beyond its own choosing, the element of excitement comes in, always a confusing factor in measures or results.

Soon the greatest joy will be to play with others of its kind. Impressions from inanimate and other objects will no longer satisfy. Then comes the period of childish games, when running, shouting, rolling about, give tone to muscle and brain. The cerebral part of this partnership, by the way, is largely limited to balancing and the motor functions generally. When, in the course of progress, a certain time comes, by common consent, wherein systematic teaching should be had, then must the bodily powers and parts receive the closest scrutiny. No school system is adequate which does not consider the training of the body as of almost equal consequence with the mind. I venture to assert with small fear of contradiction that no school is fit for your children or for mine which does not supply intelligent medical supervision. Among the more comfortable classes this will be supplied by the family physician, who may have at one time or another sufficiently looked after our boys or girls. When this is not done among those who use the large public schools, a skilled medical supervisor should be provided who shall pass judgment upon every single scholar. Thus will be brought to light heretofore unrecognized weaknesses, and, moreover, a surprising number of deformities; or in the needful repetitions of these examinations hurtful tendencies may be early recognized. In the matter of the eye supervision is becoming pretty generally exercised, and much good already accomplished thereby. Of even more importance, however, is the question of weak hearts, unsymmetrical backs and limbs, narrow chests and twisted pelves. Soon or late calisthenic exercises, military drill, class singing, or some systematic form of body training will be a regular part of the day's instruction in most schools. A steady advancement is being made in the wisdom of educational authorities in all lands. To be sure, we may never attain to that almost perfect system of education pursued by the early Greeks, the products of

which are types of physical and mental beauty which shall serve as models for all time. Then, the pedagogue, the man who walked and talked with his scholars, was equipped with wisdom as well as learning, and capable of intelligently directing the activities of his pupils in body as well as mind. We may hope to have more of this open air object teaching by stream and field, which now is used to supplement the didactic instruction in many large schools and colleges. As parents become more thoroughly aware of the economic needs of educational measures, they will demand as much, or more, of physical care for their children at the hands of the instructors.

Let us turn for a moment to the subject of spinal deformities. This is a typical result of the ordinary school life, when either unduly prolonged or unprovided with proper safeguards in the way of daily supplies of opportunities of exercise. I quote from Dr. J. K. Young, a well-known orthopedist of this city: "The great majority of cases of this curvature originate in children from the age of five or six and upward, and young persons who have been recently in school. This might be thought a mere coincidence, for the school period is necessarily that of development and curvature is a disorder of development. But there is evidence to show that school work and customs are genuine causes, not the sole causes, certainly, but very prominent ones. The origin of latent curvature depends chiefly on two things, weakness of the muscles which support the spine and bad position of the body. Weakness, though not a necessary circumstance, is an extremely common and important one. A bad position constantly maintained will twist the most athletic frame."

Again, Dr. Buckminster Brown, says: "A most pernicious habit, and one which I have very often noticed in school girls, and less often in boys, is that while we are talking to them or during recitations, they stand on one leg. This position is assumed involuntarily, and it is almost always on one and the same leg to which the weight is thrown. The effect of this is easily understood. One side of the pelvis is lifted up, curving the spine on the loins; the opposite leg

is advanced in front of the other, twisting the pelvis and rotating the vertabræ. Of course, the curve of compensation takes place between the shoulders; one is depressed, the shoulder blade gradually projecting, and with the change, and, in fact, assisting to produce it, occurs the spinal twist."

These various warping agents which are inevitable among children confined to the school seats, or to the small variation of standing at their tasks, produce a large amount of actual damage, which remains as seed from which worse trouble grows, or simply impairs constitutional vigor. A large proportion of these are transient effects and overcome by wholesomer living later, hence, never are recognized *per se*. Statistics on the subject are not yet sufficient; a single illustrative instance, however, is significant.

Guillaume, in 1864, examined the schools of Neufchâtel, and found in 350 boys, eighteen per cent. affected with spinal warping, and among 381 girls, forty-one per cent. Careful searching in other schools would give at least analogous results. Now, what is the preventive for this? I quote the uniform opinion of several authorities, who one and all recommend varied muscular activities taken at suitable times as the most important measure. The best are vigorous out-door measures, games, leaping, running, climbing, and all sorts of hard play, the more varied the better.

These should, of course, be not unduly prolonged; especially for girls, it is harmful for them to make large scores at the skipping rope and long match games at tennis or even croquet. Indeed, the best forms of exercise for children are those which speedily shift their consecutiveness and are interspersed with ample periods of rest. In girls there exists an inherent, ofttimes ineradicable indolence, a delight in sacrificing themselves to the proprieties, a misguided sense of decorum which early hinders their right indulgence in active sports. In this their mothers encourage them blindly, even the best of mothers. This early subordinating of their physical impulses leads also to a disregard of the calls of nature, the emptying of the bowels and bladder, and lays the train for life-long discomforts and disturbances.

No one but an active practitioner of medicine can believe how universal is the prevalence of torpid bowels and inactive bladders among the female sex. They seem to revel in the discomforts which arise from the neglect of these most vitally important functions. Again, this inactivity lessens their taste for water, since they rarely sweat. Hence, in unnumbered ways is it important to insist upon much activity among children.

The ordinary sports of boyhood and youth are invaluable. If ample opportunities by stream and field are afforded excellent results follow in healthful and beautiful forms. The tendency is, however, to work along lines of least resistance to specializations and to emphasize already well-marked aptitudes.

This pursuit of out-door sports is necessarily limited to the very few, Dr. Sargent says to probably less than one per cent. of our vigorous young men. Even among the members of athletic organizations only ten per cent. are really active. He goes on to say: "The cause for so little general interest in athletics is due to an increasing tendency with us, as a people, to pursue sport as an end in itself rather than as a means to an end." In making excellence in the achievement the primary object of athletic exercises we rob them of half their value in various ways by (1) increasing the expense of training; (2) by increasing unduly the time devoted to practice; (3) by reducing the number of active competitors; (4) by relying upon natural resources rather than upon cultivated material; (5) by depriving the non-athletic individuals of incentive to physical exertions; (7) by depriving them of their efficiency as a means to health. He points out the fact that the harmonious development of the physique, and the building up and broadening out of the highest types of manhood and womanhood ought to offer inducements enough for which to work.

As to how this may be best accomplished deserves special and constant study—not only for means but incentives. When obvious defects exist judicious, skilled direction is needed in such matters. At Amherst systematic class work obtains good results. In Princeton this was

done in my day by compulsory drill-work with Indian clubs, etc. Military drill has immense value. In the German Turngemeinde all over our country as well as the Fatherland classes from the youngest to the oldest drill in calisthenics regularly, and these are supplemented by out-door work—long walks in vacation time and to a limited degree field sports. The best results come from systematic measures.

For those who need remedial training by movements, the system of Ling is beyond all praise. A host of followers have taken up his suggestions and variously elaborated them and claimed originality for their views, more or less false indeed, but all acting upon his clearly defined principles.

One conclusion stands out clear and distinct from all this inquiry. It may be accepted as almost an axiom that no instance of organic lesion is yet demonstrated to be the direct and sole result of bodily exercises or competitions in one adequately trained.

Rowing.—Dr. John E. Morgan made the first systematic inquiries into the health of rowing men by collecting data from members of the Oxford and Cambridge University Crews down to the year 1872. His data are from 294 men. "The analyses made," he says, "seem to show that if harm really was done by too great strain being laid on the system in early life, that harm may generally be accounted for either by the existence of constitutional unsoundness, or by some deviation from the commonly accepted laws of prudence." Out of these 294 men, 115 considered themselves benefited by their exertions; 162 as in no way injured; 17 were inclined to think, or their friends were, that some injury had been received. Upon careful examination of these 17, 5 had consumption, 3 confined their accusations to the change from extreme activity to a sedentary life, and 5 simply supposed themselves injured, but were alive and in fair health twenty years after. Of the deaths occurring among these 294 men some were from acute illnesses. Calculating the aggregate of years lived up to 1869 by the 294 rowing men, and comparing the expectation of life of these living, according to Dr. Farr's life tables,

he found that the sum of years exceeded the number of years of the expected life tables of the same number of healthy men at the age of twenty. The lives were not shorter, but longer by 2·2 years a man than could have been expected at the time of their first rowing.

Dr. E. H. Bradford, of Boston, succeeded in obtaining, with a fair degree of certainty, the conditions of health of all the members of the Harvard Crews up to the year 1870. He admits his facts possessed less value than those of Dr. Morgan, inasmuch as rowing was then but a recent custom in American colleges. He collected data from 150 men who had participated in the annual University races between Harvard and Yale. Of these 113 were from the classes between the years 1852 and 1870, inclusive. The 37 oarsmen of the classes between the years 1870 and 1876 are rejected, as but a comparatively short time having elapsed since their contest. Of the 113, 13 died in the army and 11 elsewhere. The deaths occurring among these were critically searched for unusual causes, and very few could be directly traced in any way to their competitive exertions. The estimated excess of these actual lives from the insurance tables, over the ordinary expectation, was decided and ample. He points out that it may be urged against this method of reasoning that the oarsmen in these contests are necessarily picked men, and hence the ordinary rates of expected life are calculated for the average man, and hence too low for such instances of marked physical perfection. This objection, however, does not stand against the figures of Dr. Morgan, as he also calculated from insurance tables which only take selected risks. I may say, however, that the physical perfection of these men is practically confined to their demonstrable physical activity, and not judged of from inherited qualities, whereas many times young men fully competent to race would be rejected by careful companies on either their bad family history or personal history of past illness, etc.

Dr. Bradford then goes on carefully to compare the evil effects usually attributed to rowing with the causes of death of the deceased members of the various crews, and

arrives at most just conclusions. These estimated effects, as from rowing, are:

(1) Severe exhaustion after the race.

(2) Disturbance caused by change from the active life of regular rowing to the habits of ordinary life.

(3) Consumption.

(4) Heart disease.

(5) Nervous debility.

It is popularly supposed that profound exhaustion after a race is very common. Newspaper and other sensational reports of races frequently speak of its having occurred. Dr. Morgan could find no instance in the Oxford and Cambridge races so considered by him, nor has Dr. Bradford been able to find any among the Yale and Harvard regattas. He mentions an instance of fainting which was reported as occurring in one of the intercollegiate races at Saratoga Lake, and attributed to a felon on the finger of the sufferer. I know all about this episode, and was myself with the crew that year. The man was my room-mate and had suffered agonies from a felon for days before. He had not slept and scarcely eaten. It was an act of folly on the part of the captain to allow him to row. He was not injured by the race other than locally and temporarily. He lived twelve years after, and died from the effects of diseased appetite, but was a Hercules to the very end. A professional oarsman did die during a sculling race, the exciting causes of which was probably the race.

Exhaustion unattended with remote damage is common in scrub matches, or hastily improvised contests gotten up for fun. Here no suitable preparation has been made by proper training, hence becoming "pumped" or "winded" is inevitable, and practically harmless in healthy young men. I know of one such in which a man fainted in the boat with myself, or immediately after getting out. On regaining consciousness vomiting set in and an indigested meal of huge size stood revealed. This meal was eaten in the protesting presence of the rest of the crew immediately before the race, this individual having arrived late at the rendezvous. He is to-day a vigorous man. A hard race by men

in good condition, of which I have seen many, never produces any obvious distress. It is the part of ordinary prudence for each man to be carefully examined by a competent medical man before undertaking such quest. If he advise against this, let him not race. Even then, however, moderate exercises may safely be followed by him with much advantage.

(2) That a man should sadly miss the delightful buoyancy of feeling which is the possession of the trained athlete, once the exigencies of life demand the putting of his hand to the dull plow of needful toil, goes without saying. Just so the child misses his merry romping days on being forced into the restraints incumbent upon civilized usages. Perhaps the man would be better in morale and physique for a moderate continuance of his muscular activities judiciously mingled with his compulsory bread-winning activities. Indeed, it is often solely his fault if he fails to secure this. So, indeed, is it found best to provide the boy alternate work and play that he may develop best. There need be no sudden precipitous dropping from the river or ball field to the clerical desk. When the ex-athlete gives up suddenly all participation in his old mode of life, it may safely be set down as largely due to choice. The stimulus of a competition removed, one's inherent laziness asserts itself. Hence, doubtless, of one kind or another cause discomforts or worse. The question should not be what harm does this training beget: rather, how much good is wrought for this lazy fellow who for even so brief a space has been kept clean and active. As a matter of fact, healthy men who have become fond of field sports in the most active lines, as time creeps on and their youthful elasticity wanes, take up one and then another of the more passive forms of exercise. Thus small harm can be claimed to result from their whilom exceptional vigor. If it should seem to be so, proof is needed to eliminate such factors as sloth or greed, appetites for food, drink or tobacco. An illustration of the flimsy answers given by those prejudiced against such sports, is the reply of one of the oarsmen who asserted that the changed manner of life after a race brought on, in his case, *an attack of typhoid fever.*

(3) *Consumption.*—There is no competent evidence to prove that this is directly produced or precipitated by rowing contests. A relatively small number of the deaths among these college rowing men was due to this. As I pointed out before, a man capable of doing excellent work in a boat may inherit a tendency to consumption, and this man may yield soon or late to his inherent weakness.

(4) Upon the heart these long sustained physical strains might seem to work most dreaded damage. Dr. Morgan reports three cases of heart disease, and one man with hypertrophied and dilated heart twenty years after his last race. This makes a total of four instances of heart trouble in 294 men, or 13·6 per cent. This is not very far from the average among the records of men in armies.

(5) Nervous debility as a result of racing is not seen, except temporarily.

The Harmful Effects of Physical Exercises.—I have pointed out those discomforts resulting from bodily exertions, and now will give faithfully all I have been able to learn of the permanent danger which comes from these practices. Much exaggeration is indulged in by those who disapprove, and they exhibit some malevolence and small knowledge of the matter. In a careful and long-protracted search from all practicable sources, I have found few instances of organic lesion due to over-exertion. My inquiries were directed to certain physicians, themselves athletes of note, who continued to take interest in the subject; next, directors of large gymnasia, athletic clubs, the *Schriftwarts* of the Turngemeinde, sporting editors and writers on sporting matters, trainers of deserved repute, professional athletes of ripe age and competent to form judgments. Also I put the question directly to college professors who were known to exhibit interest in athletics—here adding to questions of instances of hurt, their views on effect upon the morale of their colleges exerted by athletics.

I made special inquiry also as to the present state of old athletes, professional and other, over fifty years of age—their present bodily state, somewhat over-elaborately, I fear, since I met with small reward. Many cases I have of old

professional acrobats and oarsmen in perfect health over seventy. A fuller study of these will be made and the results given * I can only now very briefly outline my conclusions, partly because I am trespassing overmuch on your time, and partly because the data has come in very slowly, and requires much revision and further questioning. It may be my privilege to place this matter before you at another time. Suffice now to say the first point to be made is, What was the state of these men before beginning to compete in contests of speed, endurance or strength?

The answers are meagre, but in some cases most suggestive. A gentleman, Mr. R ——, prominent as Director of Track Athletics at Princeton for many years, tells me he was a wretched, feeble lad on entering college, and is now, quite ten years later, and after having made some rare records, in sturdy, settled health. This is typical of many answers I get—a feeble youth recognizes grave physical shortcomings, systematically conquers these and finally excels. Several have told me they took systematically to open-air sports to overcome a "tendency to consumption," whatever that may mean. I have known of a few who after years of athletic life finally die of consumption. The number is small and the instances are inconclusive as to causation. I know of a gentleman whose family are closely related to me being told in youth he had heart disease, who, on his own responsibility, went regularly to Wood's gymnasium in New York, and became an all-around athlete whose fame became continental. He died at seventy-three of heart disease, living carefully, but as he chose, and to the very end enjoying vigorous health.

The inquiry into antecedent health, however, promises little. The data obtained is misleading to the last degree. Of greater interest—but beside the present inquiry—is the benefits which can be shown to have accrued from systematic pursuit of athletic sports. This question I am yet working upon—when this be tabulated—if it be in the bounds of possibility, the results will be so large as to com-

* See *Jour. Am. Med. Assoc.*, June 4, 1892.

pletely overshadow the evil effects. One conclusion is uniformly prominent in the instances of damage from boat and other racing. Always the training was either insufficient or bad, or both. For instance, I knew of a man who worked with me daily at Barrett's gymnasium here in Philadelphia years ago, and who then enjoyed a reputation for recklessness in all feats, and but little skill or strength. What he did was wastefully done ever and without any definiteness of aim. He was invited to row in a crew as substitute three days before a race. He did so and collapsed. He is said to have heart disease, what form I know not. He is still alive and a bread-winner for twenty-years.

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

BY EMRICK A. WERNER.

In the following pages I will show how can be found the positions of moving single loads, inducing the maximum and minimum stresses in the members of three-hinged arches or suspension bridges.

The investigations are based upon my "General Theory of Jointed Bow Girders," published in the *Journal of the Franklin Institute*, May to October, 1888, from which I will reproduce here, for the convenience of the reader, in short words, the theorems used in this paper.

Conditions.—Only arches or suspension bridges on two supports without cantilever brackets will be considered.

The arch or suspension bridge shall always have *three-hinged joints or hinges*, one at each abutment—*A* left, *B* right and one *C* in the middle between them. The stiffening structure shall be a *truss*.

Loads.—The bridge may be loaded in any way, with loads of any kind, single or uniformly distributed, at rest or moving, covering parts or the whole of the structure.

Line of thrust is the locus of the points of application of

the thrust *in the span*. The line of thrust is a plane curve of any form, passing through the three hinges *A C B*. It is independent of the form of the bridge. (See *Fig. 2.*)

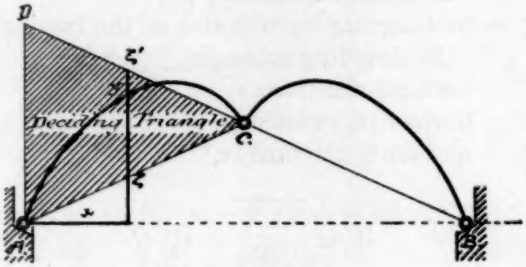

FIG 1.

Deciding triangle is found in connecting the hinges *A* and *B* with *C* and producing the lines *A C* and *B C* to the intersection *D* with a vertical at the abutment.

Loads, line of thrust and deciding triangle are variables

EXTERNAL FORCES.

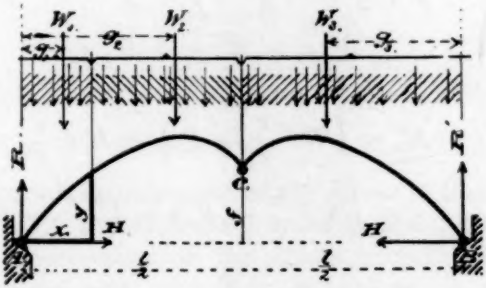

FIG. 2.

$A\ C\ B$ = line of thrust, referred to rectangular coördinates, x, y, the origin lying in A, the x axis passing through B.

$W_1\ W_2\ W_3$ = all the loads from o to x, from x to C and from C to B;

$g_1\ g_2\ g_3$ = abscissæ of the points of application of $W_1\ W_2\ W_3$.—$g_1\ g_2$ positive from the left to the right, g_3 positive from the right to the left:

p = loads taken up in the panel point;

Δx = length of panel;
l = span = distance from A to B;
f = rise = distance of top binge C above the abutment hinges;
x, ζ', ζ = rectangular coördinates of the two cathedes of the deciding triangle;
$R_1\ R'$ = vertical reactions;
H = horizontal reaction;
M_x = moments in point x.

$$R = \frac{R\,l}{l} = \frac{W_1\,(l - g_1) + W_2\,(l - g_2) + W_3\,g_3}{l}$$

$$R' = \frac{R'\,l}{l} = \frac{W_1\,g_1 + W_2\,g_2 + W_3\,(l - g_3)}{l}$$

$$H\,f = \left(\frac{R\,l}{2} - R_f\right) = \left(\frac{R'\,l}{2} - R'_f\right)$$

$$H = \frac{1}{f}\left(\frac{R\,l}{2} - R_f\right) = \frac{1}{f}\left(\frac{R'\,l}{2} - R'_f\right)$$

$$= \frac{W_1\,g_1 + W_2\,g_2 + W_3\,g_3}{2\,f}$$

$$M_x = \left(R\,l\,\frac{x}{l} - R_x\right) - H\,f.\frac{y}{f}$$

$$= \left(R\,l\,\frac{x}{l} - R_x\right) - \left(\frac{R\,l}{2} - R_f\right)\frac{y}{f}$$

$$= \left[R'\,(l - x)\,\frac{x}{(l - x)} - R'\,x\right] - H\,f.\,\frac{y}{f}$$

$$= \left[R'\,(l - x)\,\frac{x}{l - x} - R'\,x\right] - \left(\frac{R'\,l}{2} - R'_f\right)\frac{y}{f}$$

$$= W_1\,g_1\left(1 - \frac{2\,f\,x + l\,y}{2\,f\,l}\right) + W_2\left(x - \frac{2\,f\,x + l\,y}{2\,f\,l}\,g_2\right) +$$

$$+ W_3\,g_3\,\frac{2\,f\,x - l\,y}{2\,f\,l}$$

$$1 - \frac{2\,f\,x + l\,y}{2\,f\,l} = a = \frac{\zeta' - y}{2\,f}$$

$$\frac{2fx + ly}{2fl} = \beta = \frac{\zeta + y}{2f}$$

$$\frac{2fx - ly}{2fl} = c = \frac{\zeta - y}{2f}$$

$$x - \frac{2fx + ly}{2fl} g_2 = b = \left(x - \frac{\zeta + y}{2f} g_2\right)$$

$$M_x = \frac{\zeta' - y}{2f} W_1 g_1 + W_2 \left(x - \frac{\zeta + y}{2f} g_2\right) + W_3 g_3 \frac{\zeta - y}{2f}$$

$$= a W_1 g_1 + W_2 (x - \beta g_2) + c W_3 g_3$$

$$= a W_1 g_1 + b W_2 + c W_3 g_3$$

Stresses in the Stiffening Truss.—

$$C_x = \left(\frac{M}{h}\right)_x + H$$

$$= \frac{\zeta' - (y \pm h)}{2f} W_1 g_1 + W_2 \left(x - \frac{\zeta + (y \pm h)}{2f}\right) g_2 +$$

$$+ \frac{\zeta - (y \pm h)}{2f} W_3 g_3$$

$$= a W_1 g_1 + W_2 (x - \beta g_2) + c W_3 g_3$$

$$= a W_1 g_1 + b W_2 + c W_3 g_3$$

or, the horizontal component of the stress in the chord C_x in the point x of the stiffening truss is always equal to the horizontal component of the stress from the moments of the external forces

$$\left(\frac{M}{h}\right)_x$$

in the point x, plus or minus the horizontal component of the thrust H of the external forces.

h = depth of stiffening truss.

$$D_x = C_x - C_{x-\Delta x} = \Delta C_x = \left(\frac{M}{h}\right)_x - \left(\frac{M}{h}\right)_{x-\Delta x}$$

or, the horizontal component of the stress in the diagonal D_x in the panel x of the truss is equal to the difference of the

horizontal components of the stresses in the chord pieces to the right C_x and the left $C_{x-\Delta x}$ of the panel point x.

$$P_x = C_x \tan \mu_{x\ \Delta x} - C_{x-\Delta x} \tan \mu_x \pm D_x \tan a_x \pm p$$

$$= C_x (\tan a_x \pm \tan \mu_{x+\Delta x}) - C_{x-\Delta x} (\tan a_x \pm \tan \mu_x) \pm p$$

μ, a being the angles of the chord pieces and of the diagonals with the horizontal. p = load taken up in the panel point. or, the stresses in the posts are equal to the sum (algebraically) of the vertical components of the stresses of all the members intersecting in the panel point x.

Stresses in the Cable (Special Strut) and Suspension Rods.—

$$B = H$$

or, the horizontal component of the stress in the cable B is equal to the horizontal stress of the thrust H.

$$E_x = H (\tan \mu_{x+\Delta x} - \tan \mu_x)$$

or, the vertical stress in the suspension rods E_x in the point x is equal to the difference of the vertical components of the stresses in the cable (special strut) to the right $H \tan \mu_{x+\Delta x}$ and the left $H \tan \mu_x$ of the point x.

All the stresses are sums (algebraically) of stresses from the moments of the external forces. The general equation of any stress is thus:

$$\text{Stress} = a\ W_1 g_1 + W_2 (k - \beta g_2) + c\ W_3 g_3$$

$$= a\ W_1 g_1 + b\ W_2 + c\ W_3 g_3$$

the stresses differing merely in the values of the $a\ b\ c\ \beta$, which are found in adding as directed above the $a\ b\ c\ \beta$ of the chord stresses C making up the stress in question.

$a\ b\ c\ \beta$ can have any value and be positive and negative.

Maximum Line of Stress.—

$$g_m = \frac{k}{\beta}$$

it is found from $b = o$

a, c correspond to dividing lines of the loads, g_m corresponds to the dividing line of the positive and negative increments of $b\ W_2$, hence $(g_m - x)$ is that part of the

truss from x towards the top hinge, which must be loaded to make b W_2 a *positive maximum.*

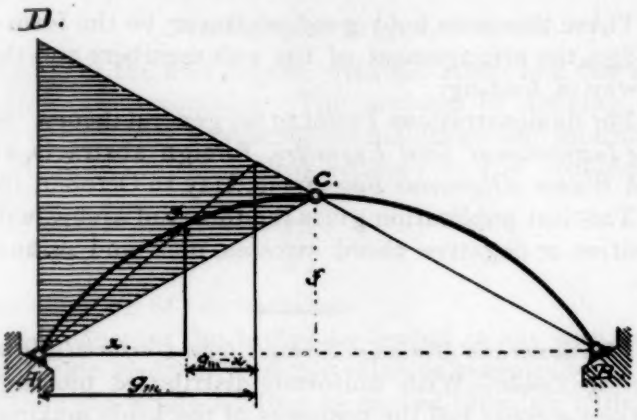

FIG. 3.

Maximum span of the stress are those parts of the truss corresponding to positive $a\ b\ c$, or to $(g_m - x)$ and positive a and c.

Minimum span of the stress are those parts of the truss corresponding to negative $a\ b\ c$ or to

$$\left(\frac{l}{2} - g_m\right)$$

and negative a and c.

Maximum and Minimum Stress.—As $W_1 g_1$, $W_2 g_2$, $W_3 g_3$ do not change their signs, *the maximum of any stress* is found with moving loads, *in loading* those parts of the truss corresponding to positive $a\ b\ c$, or in loading *the maximum span of the stress* in such way, that $W_1 g_1$, $W_2 g_2$, $W_3 g_3$ are maxima.

The minimum of any stress is found with moving loads, *in loading the minimum span of the stress,* or those parts of the truss corresponding to negative $a\ b\ c$, in such way that $W_1 g_1$, $W_2 g_2$, $W_3 g_3$ are maxima.

For members, in which the stress is an explicit function of p = the load taken up in the panel point, that end of the member, taking up no moving load, so as to have p = constant, must be selected in defining the positions of the

moving loads corresponding to the maximum and mininum stress.

These theorems hold good whatever be the form of the bridge, the arrangement of the web members and the kind or way of loading.

For demonstrations I refer to my general theory. See also *The Institution of Civil Engineers*, foreign abstracts, vol. xcv and *Wiener Allgemeine Bauzeitung*, May to October, 1891.

This last publication gives the theory of arches with only positive or negative chord stresses, plus and minus lines, etc.

Maximum and Minimum Stresses from Uniformly Distributed Moving Loads.—With uniformly distributed moving loads we can *a priori* tell the positions of the loads making $W_1 g_1$, $W_2 g_2$, $W_3 g_3$, maxima and have thus the following:

Rule.—To find, with uniformly distributed moving loads, the *maximum stress* in any member of a three-hinged arch or suspension bridge, load fully the *maximum span of the stress.*

To find the *minimum stress*, load fully the *minimum span of the stress.*

For any other kind of loading the positions of the loads making $W_1 g_1$, $W_2 g_2$, $W_3 g_3$, maxima cannot be told beforehand and special investigations must be made in each case.

The definition of the corresponding positions for *maximum and minimum stresses from moving single loads* is the subject of this paper, to which I turn now.

In the general equation

$$\text{Stress} = a\ W_1 g_1 + b\ W_2 + c\ W_3 g_3$$

The variables are:

(1) The loads;
(2) The line of thrust;
(3) The deciding triangle as the rise of the arch; and
(4) The way of loading g.

In our case we need only to know the influence of the

position of the loads g upon the value of the stress. Hence, all the variables with exception of g will be constants, and the equation will be reduced to

$$S = \text{Stress} = \phi\,(g_1\, c)$$

an equation of the first degree, with the stress and the way of loading g as variables. The problem of defining the position of the loads producing the maximum and minimum stress in any member is thus reduced to the problem of finding

$$\frac{d\,s}{d\,c}$$

from an equation of two variables.

To that effect let the bridge be loaded in any way, with moving single loads only, of any value or magnitude.

Let then the whole loading be moved infinitely little, so that no load enters or leaves the bridge, and let the increment

$$\frac{d\,s}{d\,g}$$

be derived.

The stress will then be a maximum or minimum in a dividing line—g being the variable—when the value of

$$\frac{d\,s}{d\,g}$$

goes from positive, through zero, to negative values, or *vice versa, or when*

$$\frac{d\,s}{d\,g}$$

is of different sign to the right and left of the dividing line.

With single loads, this condition can only be verified, *when one of the loads is acting in the dividing line.*

$$\frac{d\,s}{d\,g}$$

will give the conditions of a maximum or a minimum, accordingly as the maximum or minimum span of the stress is loaded.

It remains to give the explicit forms of

$$\frac{d\,s}{d\,g}$$

Increment of the Stresses in the Chords

$$\frac{d\,s}{d\,g} = \frac{d\,C}{d\,g}$$

We have

$$C_x = a\,W_1 g_1 + W_2 (x - \beta\, g_2) + c\,W_3 g_3$$

moving infinitely little, say to the left, it follows

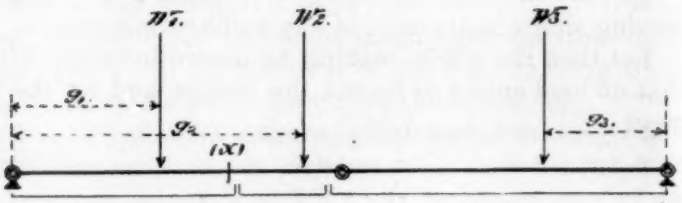

FIG. 4.

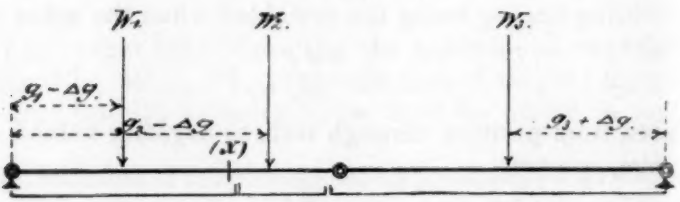

FIG. 5.

$$C_{\Delta x} = a\,W_1(g_1 - \Delta g) + W_2[x - \beta\,(g_2 - \Delta g)] + c\,W_3(g_3 + \Delta g)$$
$$C_x = a\,W_1 g_1 \qquad + W_2[x - \beta\, g_2] \qquad + c\,W_3 g_3$$

$$\frac{d\,C}{d\,g} = -a\,W_1 + \beta\,W_2 + c\,W_3$$

Increment of the Stresses in the Diagonals

$$\frac{d\,s}{d\,g} = \frac{d\,D}{d\,g}$$

As known, the equation $D_x = \Delta\, C_x$ = difference of two

moment stresses, will give only true values, when on the length Δx separating C_x and $C_{x-\Delta x}$ no finite load is acting. Hence, if loads are acting in the length Δx, they must first be transferred according to the law of the lever to the panel points.

It is again

$$D_m = a\ W_1 g_1 + W_2 (k - \beta g_2) + c\ W_3 g_3$$

and in calling w the loads acting in the panel x and w_1 and w_2 the parts of w transferred according to the law of lever, to the panel points, this equation gives

Moving infinitely little we have

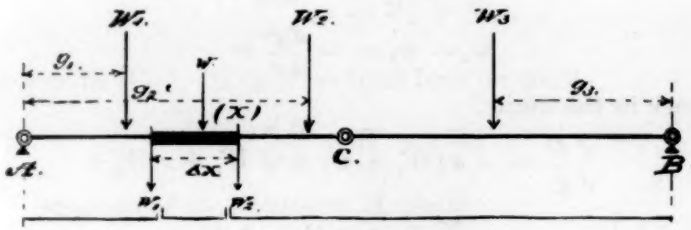

FIG. 6.

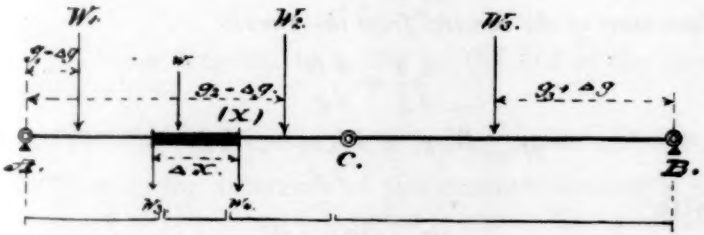

FIG. 7.

From these figures we deduct

$$D_{\Delta x} = W_1 (g_1 - \Delta g) + W_2 [k - \beta (g_2 - \Delta g)] + c\ W_3 \times \\ \times (g_3 + \Delta g) + a (x - \Delta x)\, w_3 + (k - \beta x)\, w_4$$

$$D_x = W_1 g_1 + W_2 [k - \beta g_2] + c\ W_3 g_3 + a (x - \Delta x)\, w_1 + \\ + (k - \beta x)\, w_2$$

$$D_{\Delta x} - D_x = [-a\ W_1 + \beta\ W_2 + c\ W_3] \Delta g + a (x - \Delta x) \times \\ \times (w_3 - w_1) + (k - \beta x) (w_4 - w_2)$$

But it is

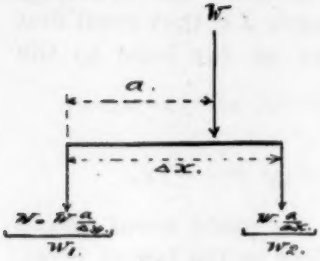

FIG. 8.

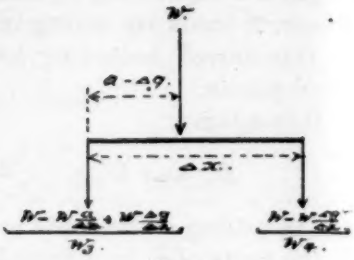

FIG. 9.

whence

$$w_3 - w_1 = + \frac{\partial g}{\partial x} w$$

$$w_4 - w_2 = - \frac{\partial g}{\partial x} w$$

thence in the limit:

$$\frac{d D}{d g} = - a (W_1 + w) + \beta W_2 + c W_3 +$$

$$+ \frac{w}{\partial x} [a x - (k - \beta x)]$$

Increment of the Stresses from the Thrust

$$\frac{d s}{d g} = \frac{d H}{d g}$$

$$H = \frac{W_1 g_1 + W_2 g_2 + W_3 g_3}{2 f}$$

or with

$$W_1 + W_2 = W_1$$

$$H = \frac{W_1 g_1 + W_3 g_3}{2 f}$$

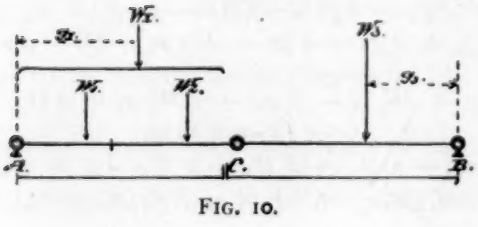

FIG. 10.

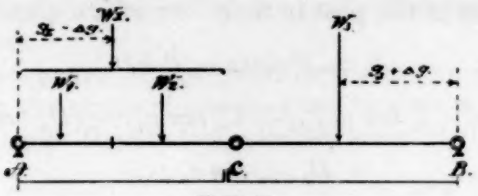

FIG. 11.

moving infinitely little, it follows

$$H_{\Delta x} = [W_1 (g_1 - \Delta g) + W_3 (g_3 + \Delta g)] \frac{1}{2f}$$

$$H_x = [W_1 g_1 + W_3 g_3] \frac{1}{2f}$$

$$\frac{dH}{dg} = - W_1 + W_3$$

and with $W_1 + W_3 = W$ = total load on truss

$$\frac{dH}{dg} = W - 2W_3$$

Increment of the Stresses in the Posts

$$\frac{ds}{dg} = \frac{dP}{dg}$$

(1) If *one* diagonal is acting at the end of the post, the stress will be

$$P_x = C_x (tan\ a_x \pm tan\ \mu_{x+\Delta x}) - C_{x-\Delta x} (tan\ a_x \pm tan\ \mu_x)$$

or equal to the difference of two moment stresses or to one moment stress, if one C is equal to zero. The maximum or minimum of P_x is thus found as for C or D, as the case may be.

If *one* diagonal, resisting tension and compression, is used in the panel, *one* set of general equations will give the maximum and minimum. If only diagonals *in tension* are used, *two* sets of general equations are necessary, one for each diagonal to find the maxima.

(2) If *two diagonals* are acting together at the end of the post, consider the post as consisting of two coinciding posts *P right* and *P left*, each acted upon by one diagonal.

The stress in the post is then

$$P_x = P\,right \pm P\,left.$$

$$P_x = (C_{x+\Delta x}\,tan\,\mu_{x+\Delta x} - C_x\,tan\,\mu_x) \pm (D_x\,tan\,a_x \pm$$

$$\pm D_{x+\Delta x}\,tan\,a_{x+\Delta x})$$

representing the following division of W_1 and W_2.

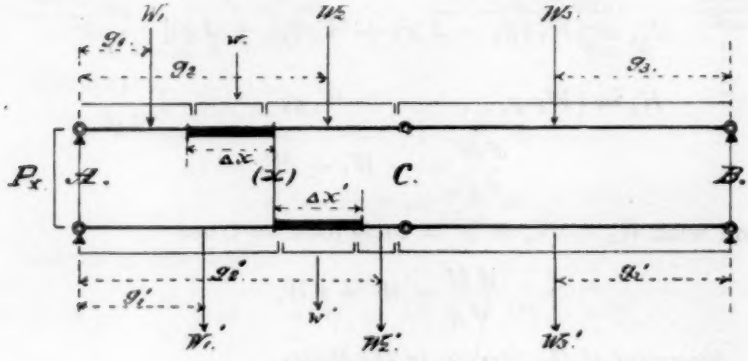

FIG. 12.

As the above equation of P shows, the stress in a post acted upon on one end simultaneously by two diagonals, is a function of the difference of two shearing forces. But for the difference of two shearing forces, *there exists no common dividing line between* W_1 *and* W_2.

Each of the posts *P right* and *P left*, acted upon by *one* diagonal, must thus be treated as a separate post and the results combined. The *maximum span* of the *combined action* of *P right* and *P left* represents thus those parts of the truss corresponding to the *combined positive a b c* β of *P right* and *P left*, and the *minimum span* corresponds to the *combined negative a b c* β of *P right* and *P left*.

If *two diagonals in tension* act together at the end of the post, the stress can never be greater or smaller than the maximum or minimum stress from *one* diagonal acting at the end of the post, and no special calculations need be made of the stress from two diagonals in tension acting

simultaneously at the end of the post. The demonstration is as follows.

In consequence of the position of the two diagonals in the panels, the stress of one diagonal is always reversed, or the value of *one* D will always be negative.

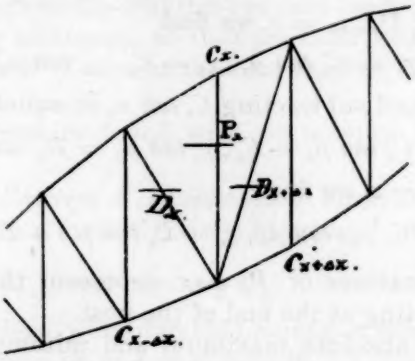

FIG 13

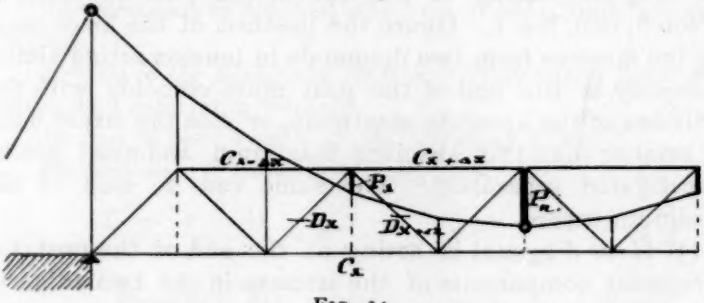

FIG. 14.

The combined action of the two diagonals is thus

$$\pm (D_x \tan a_x - D_{x+\Delta x} \tan a_{x+\Delta x})$$

and P will be

$$\pm P_x = (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) \pm (D_x \tan a_x - - D_{x+\Delta x} \tan \mu_{x+\Delta x})$$

or separating

$$\pm P_x = (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) + (D_x \tan a_x - - D_{x+\Delta x} \tan a_{x+\Delta x}) \quad (1)$$

$$\pm P_x = (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) + (D_{x+\Delta x} \tan a_{x+\Delta x} - - D_x \tan a_x) \quad (2)$$

These expressions are maxima or minima, when one of the D, as the case may be, is equal to zero.

Adding and subtracting $C_m \tan \mu_{x+\Delta x}$ in equation (1), writing

$$C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_{x+\Delta x} = D_{x+\Delta x} \tan \mu_{x+\Delta x}$$

and making $D_{x+\Delta x} = o$, we find

$$\pm P_x \, max. = (C_x \tan \mu_{x+\Delta x} - C_{x-\Delta x} \tan \mu_x) + D_x \tan a_x$$

Adding and subtracting $C_x \tan \mu_x$ in equation (2), writing

$$C_x \tan \mu_x - C_{x-\Delta x} \tan \mu_x = D_x \tan \mu_x$$

making $D_x = o$, we find

$$\pm P_x \, max. \, (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) + D_{x+\Delta x} \tan a_{x+\Delta x}$$

Both equations of P_x *max.* represent the action of *one* diagonal acting at the end of the post.

But the absolute maximum and minimum stress from one diagonal acting at the end of the post is found as directed, sub. No. 1. Hence the position of the loads making the stresses from two diagonals in tension acting simultaneously at the end of the post must coincide with the positions of the absolute maximum, or else the stress must be smaller than this absolute maximum and need not be investigated separately. The same can be said of the minimum stress.

(3) If *no* diagonal is acting at the end of the post, the horizontal components of the stresses in the two adjacent chord pieces must be the same, or

$$P_x = C_x \, (\tan \mu_{x+\Delta x} - \tan \mu_x)$$

Hence P_x can never be greater or smaller than the vertical component of C_x maximum or C_x minimum.

Remembering that when no diagonal is acting at one end two diagonals are acting at the other end of the post, we see that the maximum or minimum of P will be found in this case, when

$$C_x \text{ and } (D_x \tan a_x \pm D_{x+\Delta x} \tan a_{x+\Delta x})$$

will be maxima or minima at the same time, as the case may be.

With these expressions of the increment of the different stresses, it will now be easy to formulate the rules deciding the positions of moving single loads, which create the maximum and minimum stress in the members of a three-hinged arch or suspension bridge.

Vertical Reactions R.—Put the heaviest loads on or near the corresponding abutment, so that the total load W and the moment Wg or $W(l-g)$, as the case may be, are maxima at the same time.

The minimum is found with no moving loads at the bridge.

Horizontal Reaction H, or Horizontal Stress B, in the Cable Maximum.—Put a load at the top hinge and load the truss, so that

$$W - 2\,W_3$$

is of different sign, when the load acting at the top hinge is once counted into W_2 and once into W_3.

The Minimum is reached when no moving loads are at the bridge.

Stresses in the Suspension Rods E.—They reach their maximum and minimum with H.

Stresses in the Chords C of the Stiffening Truss.—

Maximum: (1) Calculate in figures.

$$\frac{\zeta' - (y \pm h)}{2f} = a \qquad \frac{\zeta + (y \pm h)}{2f} = \beta$$

$$\frac{\zeta - (y \pm h)}{2f} = c \qquad (x - \beta g_2) = C$$

(2) Write the general equation of C.

(3) Make $b = o$ and find the maximum line g_m.

(4) Decide the *maximum span* of C.

(5) Put a load on the dividing line and load the maximum span, so that

$$-a\,W_1 + \beta\,W_2 + c\,W_3$$

is of different sign, when the load acting on the dividing line is counted once into W_1 and once into W_2 or once into W_2 and once into W_3, as the case may be.

Minimum: Proceed as above, only use the minimum span.

Stresses in the Diagonals D of the Stiffening Truss.—

Maximum: (1) Substract $a\,b\,c\,\beta$ of $C_{x-\Delta x}$ from $a\,b\,c\,\beta$ of C_x.

(2) Write the general equation of D_x.

(3) Make $b = o$ and find the maximum line of D_x.

(4) Decide the maximum span of D_x.

(5) Put a load on the dividing line and load the maximum span, so that

$$-a\,(W_1 + w) + \beta\,W_2 + c\,W_3 + \frac{w}{J_x}\left[a_x - (k - \beta_x)\right]$$

is of different sign, when the load acting on the dividing line is counted once into w and once into W_2 or once into W_2 and once into W_3, as the case may be.

Minimum: Proceed as above, only use the minimum span.

Stresses in the Posts P of the Stiffening Truss.—In all instances select that end of the post taking up *no* moving loads for defining the positions of the loads corresponding to *P max.* and *P min.*

Maximum:

(1) *One* diagonal acting at the end of the post.

Proceed as for *D* or *C*, as the case may be.

(2) *Two* diagonals acting at the end of the post.

Consider the post as composed of two coinciding posts, *P right* and *P left*, each acted upon by one diagonal.

Treat *P right* and *P left*, each as a separate post and combine the action of both.

Note.—With two diagonals *in tension* acting at the end of the post, no special calculations are necessary, the corresponding stress being always smaller than the stress from the action of *one* diagonal.

(3) *No* diagonal acting at the end of the post.

Maximum: The value of P_x is always less than

$$C_x\,(tan\ \mu_{x+\Delta x} - tan\ \mu_x)$$

The exact value of P_x is found in making

$$C_x \text{ and } \pm\,[D_x\ tan\ a_x \pm D_{x+\Delta x}\ tan\ a_{x+\Delta x}]$$

a maximum at the same time.

Minimum: Proceed as for the maximum, only use the minimum span or the minimum of the stresses.

A check of these rules can be obtained in the following way:

Any arched truss will become a truss with only vertical reactions, when the horizontal reaction H becomes zero. Hence in making H equal to zero in the above expressions of the arch, these expressions must be reduced to the corresponding expressions of a truss with vertical reactions only. To define the conditions making H equal to zero, we have the equations of M and H.

$$M_x = R\,x - W_1\,(x - g_1) - H\,y$$

$$2\,H\,f = W_1\,g_1 + W_2\,g_2 + W_3\,g_3$$

From these equations follows that y and f must be equal to zero. M becomes then the moment of a truss with vertical reactions only. But we know that these moments can, under no circumstances be equal to zero, between the abutments. Hence the subdivision of W_2 becomes void, and we have as third condition if H shall become zero in the arch, $W_2 = o$, besides $y = o$ and $f = o$.

For a truss, with vertical reactions only the general equations are:

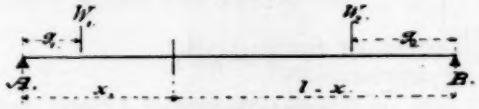

FIG. 15.

$$C_x = \left(\frac{M}{h}\right)_x = \frac{1}{h}\left[\frac{l - x}{l}\,W_1\,g_1 + \frac{x}{l}\,W_3\,g_3\right]$$

$$\frac{d\,C}{d\,g} = \frac{l}{x}\,W_1 - W$$

W = total load

$$D_x = [-\,W_1\,g_1 + W_3\,g_3]\,\frac{1}{h}$$

when h = constant.

$$\frac{d\,D}{d\,g} = W - w\,\frac{l}{\Delta\,x}$$

w = load on panel length $\Delta\,x$.

Introducing $y = o, f = o, W_2 = o$ in the equations of the arch, we find

$$1 - \frac{2fx - ly}{2fl} = \frac{\zeta' - y}{2f} = a = \frac{l - x}{l}$$

$$\beta = o \qquad W_2 = o \qquad b = o$$

$$\frac{2fx - ly}{2fl} = \frac{\zeta - y}{2f} = c = \frac{x}{l}$$

and

$$C_x = a\, W_1 g_1 + b\, W_2 + c\, W_3 g_3$$

$$= \left[\frac{l - x}{l} W_1 g_1 + \frac{x}{l} W_3 g_3\right] \frac{1}{h}$$

$$\frac{dC}{dg} = -a\, W_1 + \beta\, W_2 + c\, W_3$$

$$= -\frac{l - x}{l} W_1 + \frac{x}{l} W_3 = \frac{l}{x} W_1 - W$$

Comparing

$$D_x = a\, W_1 g_1 + W_2 (k - \beta g_2) + c\, W_3 g_3$$

with

$$D_x = [-W_1 g_1 + W_3 g_3] \frac{1}{h}$$

we see that

$$a = -1$$

$$c = +1$$

$$(k - \beta x) = c\,(l - x)$$

$(k - \beta x)$ being the coëfficient of the load acting in the point x.

Introducing in

$$\frac{dD}{dg}$$

of the arch

$$\frac{dD}{dg} = -a(W_1 + w) + \beta\, W_2 + c\, W_3 + \frac{w}{\Delta x}[a x - (k - \beta x)]$$

it will become

$$\frac{a\, D}{dg} = +(W_1 + w) + W_3 - w_1 \frac{l}{\Delta x} = W - w\frac{l}{\Delta x}$$

As we see, in the arch, the length of the span, which must be loaded, also the ratio according to which the different parts of this span are to be loaded, to produce a maximum or minimum of any stress, *is variable*, while in the truss with vertical reactions only the length of the span, which is to be loaded and the manner, in which it is loaded in each point, is constant.

Appended are the actual calculations of the stresses, in the members of an upright three-hinged arch and of a three-hinged suspension bridge.

CHICAGO, ILL., February, 1892.

[*To be continued.*]

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, June 28, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 28, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-one members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and lantern slides, which were approved and ordered paid.

Mr. D. A. Partridge exhibited and described a Thomson reflecting electrometer that he had constructed from drawings illustrating a paper on the subject by Sir Wm. Thomson. The instrument was beautifully made, and showed remarkable sensitiveness.

Mr. Paul Winand read the second part of his paper on "Some Points Regarding Multiphase Current." Referred for publication.

Prof. Edwin J. Houston gave "Some Additional Notes on the Graphic Representation of Magnetic Fields." Referred for publication.

Mr. Richard W. Gilpin described a curious changing of polarity met with in a four-pole compound dynamo.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

On POLYPHASED CURRENTS.

By Paul A. N. Winand.

[*A paper before the Electrical Section, at the stated meetings of April and May.*]

Since last year's electrical exhibition at Frankfort, the transmission or distribution of energy by means of polyphased currents, seems to have attracted, to a remarkable degree, the attention of all interested in electrical matters. This system had been proposed and experimented upon for several years previously, but it is only since the successful outcome of the Lauffen transmission that its practical advantages have been generally recognized.

Little has been published as yet in this country concerning its theoretical features, while a number of papers on the subject have appeared in Germany. As the German papers mostly treat the matter in a purely mathematical manner, which is not always favorable to clear insight into the somewhat intricate conditions, I have endeavored to apply to the question a more direct way of reasoning. I fear, however, that I have succeeded but imperfectly in my purpose.

GENERAL CONSIDERATIONS.

The term polyphased or multiphased currents has apparently not yet received a strict definition. It is broad enough to cover any system or combination of connected conductors carrying each an alternating current different in phase from the currents carried by the other conductors. In fact, however, it seems to have been used for designating such systems of alternating currents

> which *can be produced* by means of an armature without commutator, uniformly rotating relatively to a constant field and opposing to the motion a torque which is a constant during the whole of a revolution, or which, by means of stationary and

permanently connected conductors, *can generate* an uniformly rotating, constant field.

The field, in this second case may or may not be provided with iron cores of suitable shape.

The currents and electro-motive forces are generally supposed to follow the simple *sine* law, as usual.

It is possibly by looking at it in this way that the chief promoter of polyphased currents in Germany, Mr. M. von Dolivo-Dobrowolsky, has been led to propose the name of "Drehstrom," or rotary current.

It is evident that in a system of polyphased currents which conforms to the above conditions of possible origin or possible effect, the individual currents and electro-motive forces are not arbitrary, but inter-related as to amplitudes and phases.

One general and characteristic property of a system of currents conforming to this definition can be proved before going into further details.

The rate at which the total energy is generated, transmitted or absorbed in the system is the same at any moment of a period.

This follows directly from the assumption that the torque and the speed are uniform, which means that the rate of consumption of mechanical energy is constant during a period, while the efficiency of conversion is supposed, as usual to be constant during that time and because no energy is momentarily stored up in the armature.* The energy delivered at the terminals is then constant, and it will be so also through the whole system if there is no momentary storing up of energy by reason of capacity effects. Such effects may even be present without disturbing the conditions if properly distributed.

The second alternative of the definition (consisting in simply generating a field) is really equivalent to the first for the case that the torque is $= O$.

* See the paper published since by Mr. C. Steinmetz, in *Electrical World*, of July 16, 1892.

Any system of polyphased currents, however irregularly the phases may be distributed in time and however different the currents may be in magnitude, will thus be governed by this condition of uniform rate of energy together with the general laws of circuits. That the sum of the currents in all conductors of the system which any continuous infinite surface may cut is at any moment $= O$; and that the difference of potential between any two points on the conductors is at any moment equal to the sum of the electro-motive forces* along any path which may be followed along the conductors to lead from one point to the other.†

We will not dwell any longer on the question taken in its most general form, because in practical applications

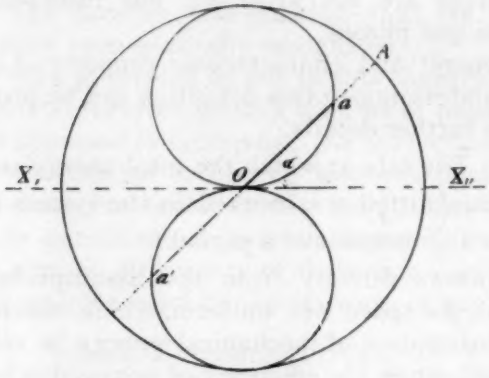

FIG. 1.

polyphased currents are (or, at least, are intended to be) symmetrical; that is, the phases are evenly distributed over the time of one period and the currents are of the same intensity.

SYMMETRICAL SYSTEMS.

The current and electro-motive force in each conductor

* These electro-motive forces include $e = i\,R$ taken with the sign of i.

† This is practically equivalent to the law stated by Helmholtz in 1853: That, if in any system of conductors there are electro-motive forces in different parts, the electric tension in any point is equal to the algebraic sum of the tensions which each individual electro-motive force would produce when acting independently of all the others.

are of necessity alternating since there is no periodical commutation of connections. They can be represented as usual by drawing a *sine* curve, and the relations between several of them can be shown by putting the curves along the same axis, but shifted by amounts corresponding to the relative phases.

It is sometimes more convenient to use, as suggested by Prof. Silv. Thompson, the geometrical property which is well known to mechanical engineers by its application in Zeuner's slide-valve diagram.

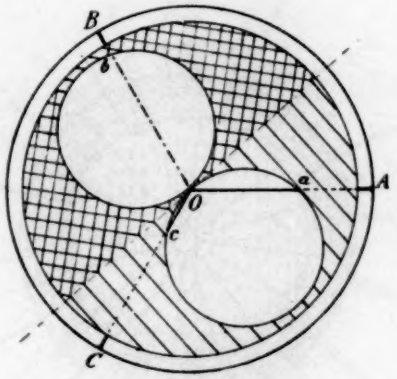

FIG. 2.

Fig. 1 represents this method, which we shall apply later on.

The length *Oa*, cut off by the small circle on the radius *O A*, is proportional to *sin a*, being the angle of *O A* with the diameter X_I *O* X_{II}. When the radius is below X_I *O* X_{II} *sin a* is negative and this is shown by the part cut off being in the lower circle, like *Oa'*.

The different length cut off on several radii drawn at angles corresponding to the phases will thus show at a glance the simultaneous values of currents or of electromotive forces in a corresponding polyphased system. If a model be made in which the radii can be rotated together, relatively to the circles, the succession of simultaneous values will appear in a striking manner. It has proved convenient to draw the radii on one sheet and to extend

them to a larger circle, while another sheet, out of which the small circles have been cut, is rotated on top of the first. The two halves of this sheet are made of different appearance, so as to show at once which quantities are positive and which are negative. *Fig. 2* shows this disposition for a three-phase system.

Polyphased generators can be built almost entirely like alternators, and, as for these, it is often convenient to have the armature stationary and the field rotating. Let us con-

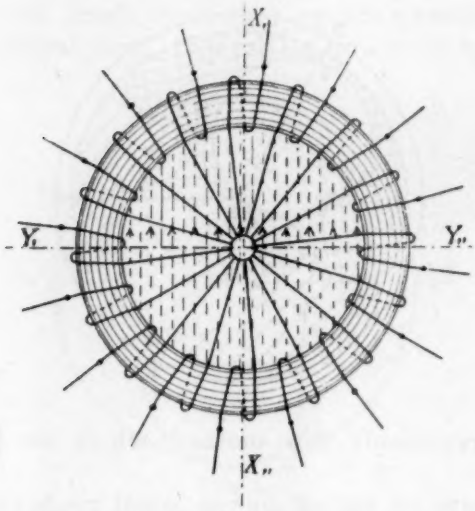

FIG. 3.

sider more closely the simple case of a ring armature with rotating bipolar internal field.

The successive coils of the armature may be connected in two simple ways:

All their right-hand ends may be connected together and their left-hand ones to the terminals of the machine, hence each to one wire of the line, as shown in *Fig. 3*. This has been called the *star* combination. Or the coils may be connected in one series, like a Gramme ring, and the points of junction connected to the terminals (*Fig. 4*), which has been called the *mesh* combination.

We may now trace the distribution of differences of potential and currents at any moment in the conductors.

$X_I\ X_{II}$ is the direction of magnetic axis, $Y_I\ Y_{II}$ a perpendicular to it. Taking each coil separately, the electro-motive force e, generated in it is maximum for the coils at $X_I\ X_{II}$ and $= O$ for those at $Y_I\ Y_{II}$, and so are the currents also, if there be no lag, which we will assume for the present.

In the *star* combination the difference of potential E_{1s} between two diametrical terminals is equal to twice the

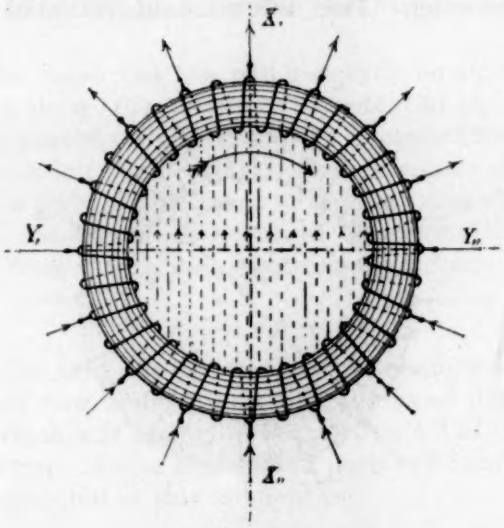

FIG. 4.

electro-motive force e of the opposite coils connected to those terminals, it is

$$E_{1s\,max} = 2e_{max}$$

for the terminals at $X_I\ X_{II}$.

The difference of potential between adjacent terminals is

$$E_{11s} = e_x - e_{x+1}$$

It is equal the difference of the electro-motive forces in the two corresponding coils.

Necessarily

$$E_1 = \Sigma E_{11}$$

for half the ring in both the *star* and the *mesh*.

In the *mesh*, however,

$$E_{11m} = e$$

so that

$$E_{1m} = \Sigma e$$

It is interesting to compare the cases where everything is the same (including amount and size of wire), the only difference being in the number of coils (or phases) and in their combination as star or mesh. It is easy to see that in mesh E_{1m} is due to the induction on all the turns of one-half of the ring. The difference of potential between

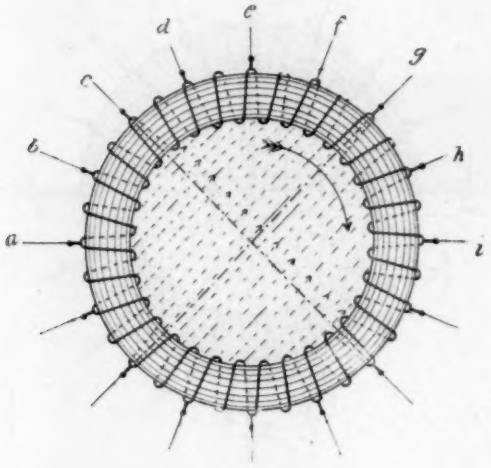

FIG. 5.

opposite terminals is thus independent of the number of coils, but the difference of potential between adjacent terminals, taken at same distance from Y_1 Y_{11} is inversely proportional to the number of coils because it is proportional to the number of turns per coil.

In star, since $E_{1s} = 2e$ the difference of potential between opposite terminals is inversely proportional to the number of coils, but the difference of potential E_{11s} between adjacent terminals is, at the same distance from X_1 X_{11}, nearly inversely proportional to the square of the number of coils.

This is due to the fact that this difference E_{11s} is not only proportional to the number of turns per coil, but also to the distance between the centres of said coils along the ring.

The field $N\ S$ may have any more or less regular shape or distribution and accordingly the electro-motive force in a coil will vary in different ways, as the case may be, with the angular displacement a or with time, as we suppose the motion uniform. For the star the law followed by the difference of potential between opposite terminals is the same as that followed by the electro-motive force in a coil.

For the mesh the law will generally be a different one. As shown above, the difference of potential is, in this case, equal the sum of the electro-motive forces induced in all the coils on one-half of the ring. The difference of potential, between a and i, for instance (*Fig 5*) can therefore, at any time, be considered as equal to electro-motive force in winding from a to h, *plus* electro-motive force induced in coil $h\ i$.

$$a\ i_1 = a\ h + h\ i$$

After the field has moved through an angle equal to the distance of two consecutive coils, the same portion of the field to which was acting on the portion $a\ h$ of the winding, is now acting on the equivalent portion $b\ i$ and the difference of potential at this moment is:

$$a\ i_{11} = b\ i + a\ b$$

The variation,

$$\Delta\ a\ i = a\ i_1 - a\ i_{11}$$

of the difference of potential between the opposite terminals a and i after this angular displacement equal to the space of one coil is thus

$$\Delta\ a\ i = a\ h + h\ i - (b\ i + a\ b)$$

but it is evident that

$$a\ h = b\ i$$

and when the number of coils is large;

$$h\ i = -\ a\ b,$$

because then coils $a\ b$ and $h\ i$ are practically opposite, if we

only assume that the field, where it meets the armature, is symmetrical around the centre of rotation.

Consequently

$$\Delta a i = 2 h i$$

or

$$= 2 a b$$

$$= 2 e$$

This means that the *variation* of the *difference of potential* between opposite terminals in the *mesh* is equal to the *difference of potential* itself in the *star*, and that, for a large number of coils (or phases), if $E_{1m} = Fa$ is the law followed by the *difference of potential* in mesh, the law followed by the same quantity in star is the derivate function

$$E_{1s} = \frac{d\,Fa}{d\,a}$$

of the preceding.

Similar considerations would show that the reverse is true for the difference of potential between adjacent terminals.

$$E_{11s} = Fa$$

and

$$E_{11m} = \frac{d\,Fa}{d\,a}$$

hence

$$E_{11s} = Fa$$

and

$$E_{1s} = \frac{d\,Fa}{d\,a}$$

and

$$F_{1m} = Fa$$

and

$$E_{11m} = \frac{d\,Fa}{d\,a}$$

There is only one form of the law for which

$$\frac{d\,Fa}{d\,a}$$

is equivalent to $F\,a$ itself; namely, when $F\,a$ is *sin a* or *cos a*,

which latter is the same as *sin a*, with one-fourth period difference of phase

$$\frac{d\,Fa}{d\,a} \text{ is then } + \cos a \text{ or } - \sin a,$$

and everything in the system, as well for the star as the mesh combination, follows the *sin a* law as long as the resistances, inductances and capacities can be considered as constants.

I will only remark further concerning this general case, that if $E = Fa$, when plotted gives curves of the kinds shown in *Fig. 6*.

$$E = \frac{d\,Fa}{d\,a}$$

gives curves like shown in *Fig. 7*.

It is generally desirable to have the currents and electro-motive forces follow the *sine* law and as this is sufficiently approximated in most practical cases, the subsequent considerations will be made under assumption of this law.

Returning then to *Fig. 3* and *Fig. 4* the rule that, for

FIG. 6.

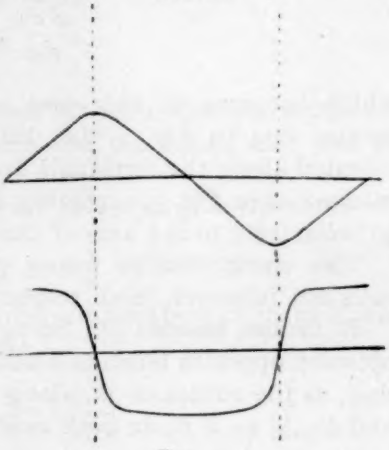

FIG. 7.

FIG. 6.

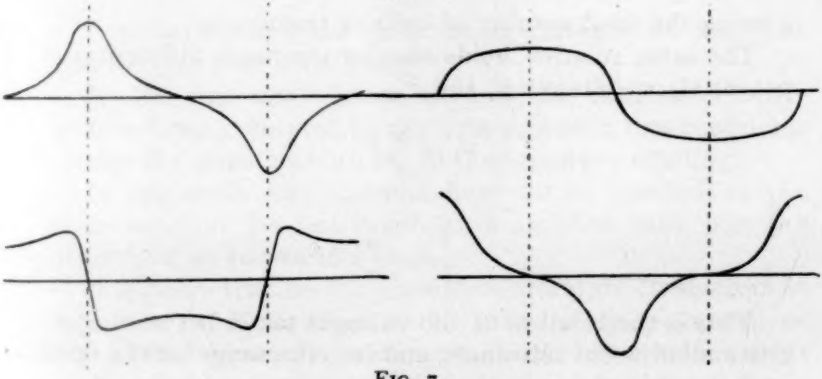

FIG. 7.

mesh and star, the difference of potential of opposite and of adjacent conductors follow the laws.

$$Fx, \frac{d\,Fx}{d\,x}$$

and

$$\frac{d\,Fx}{d\,x}, \; Fx$$

which becomes in this case *sin x*, *cox* and *cos x*, — *sin x*, means that in *Fig. 4* the differences of potential are distributed along the terminals and occur in time in the same manner as in *Fig. 3*, excepting that everything is shifted by 90° relatively to the axis of the field.

The electro-motive forces generated in the individual coils are, however, in all respects, the same in both cases.

It means, besides [E_1 being the difference of potential between opposite terminals and E_{11} between adjacent ones], that, as the values of E_{11} along the ring follow the *sine* law, and $E_{1\,max} = \Sigma\, E_{11}$ in both cases;

$$\Sigma_0^{\pi}\, E_{11} = E_{1\,max} = \frac{n}{\pi}\, E_{11\,max}$$

n being the total number of coils or terminals.

The same relation holds also for the mean differences of potential, or voltages V_1 and V_{11}.

$$V_1 = \frac{n}{\pi}\, V_{11}$$

or

$$\frac{V_1}{V_{11}} = \frac{n}{\pi}$$

This is the relation of the voltages taken between opposite and adjacent terminals, and it is the same for the mesh and the star.

Continuing now the comparison between identical machines, the difference being only in the disposition as star or mesh, we find that the voltages compare as follows:

As the coils contain the same number t of turns in both cases

$$V_{1s} = 2\,a\,t$$

$$V_{1m} = \frac{n\,a\,t}{\pi}$$

a being the voltage per turn hence

$$\frac{V_{1m}}{V_{1s}} = \frac{n}{\pi}$$

in which, V_{1m} and V_{1s} are taken between opposite terminals.

The same relation is, from the preceding, also true for adjacent terminals.

If the armatures are wound so as to give the same voltages

$$V_{1m} = V_{1s},$$

but then the coils contain different numbers of turns t_m and t_s, and the same formulæ give

$$2\,a\,t_s = \frac{n\,a\,t_m}{\pi}$$

or

$$\frac{t_s}{t_m} = \frac{2\,\pi}{n}$$

Considering now the question of currents, we may first assume that they do not lag.

In the star combination they follow then the electromotive force generated in the coils and each line conductor carries the same current, A_s, as the armature winding.

In the mesh, the currents flow out of one-half of the armature into the line conductors and flow back into the other half, as shown in *Fig. 4*.

It appears that, as the current in armature conductors is maximum at $Y_I\ Y_{II}$ (this is the case in *Fig. 3* as well as *Fig. 4*) the current is maximum in the line conductors at $X_I\ X_{II}$; that is, at 90° from where it is maximum in the star combination.

The instantaneous value C_I of the current in armature is equal to the sum of the line currents C_{II} in the conductors

comprised between this point and point X. Consequently its maximum value is equal to the sum of line currents in quadrant $X\ Y$.

$$C_{1\max} = \frac{n}{2\pi} C_{11\max}$$

and if we call A_{1m} and A_{11m} the mean values of currents in armature and line for the mesh:

$$A_{1m} = \frac{n}{2\pi} A_{11m}$$

If we compare otherwise identical armatures, the cross sections S_s S_m of wires are inversely as the numbers of turns per coil, and as we have found the latter to be

$$\frac{t_s}{t_m} = \frac{n}{2\pi}$$

in order to obtain equal voltage

we find

$$\frac{S_s}{S_m} = \frac{2\pi}{n}$$

If we consider the machines as equally loaded when the currents are proportional to the cross-sections of conductors, then, for equal load,

$$\frac{A_s}{A_{1m}} = \frac{2\pi}{n}$$

This, with the previous equation

$$A_{1m} = \frac{n}{2\pi} A_{11m}$$

shows that

$$A_s = A_{11m}$$

with which means that otherwise identical machines, one having star the other mesh winding and such number of turns as to give the same voltage, the currents in line, and consequently the energy, will be the same if they are equally loaded.

Considerations almost entirely similar to the above would show that the relations found for the currents and electromotive forces in the armature and line conductors, apply

also to conductors considered as mere resistances, such as lamps.

We have assumed that there was no difference of phase between currents and electro-motive forces. There is generally such a difference, however, but, if everything is symmetrical, the relations between the currents and those between the electro-motive forces remain unchanged, the only difference with the case assumed before being that all what relates to the currents is shifted by an angle equal to the difference of phase relatively to the axis of the field.

It would be more complicated than difficult to show further in a similar manner, that, inversely, the same field can be produced by the same polyphased system with otherwise identical cores and windings, the only difference being in the arrangement as star or mesh.

We have considered more particularly the case of a ring armature. A drum might have been taken as well and would have led to similar results.

It may be interesting to note that the first idea of Mr. Haselwander, one of the pioneers in this line, had been to take two Thomson-Houston arc machines, having armatures of the drum type, and to use one as a dynamo, the other as a motor of a three-phase system. Contact rings would have been substituted to the commutators. He afterwards made use of ring armatures.

THREE-PHASE SYSTEM.

This system has, besides its simplicity, decided practical advantages of its own, These have apparently been first fully recognized and expounded by Mr. von Dolivo-Dobrowolsky, to whose efforts the successful introduction of this system in actual practice is mainly due. We may investigate the relations in this system by means of the diagram or model represented by *Fig. 2*. It shows the star and mesh combination, $O\,A$, $O\,B$, $O\,C$ being the branches of the star, while $A\,B$, $B\,C$ and $C\,A$ are those of the mesh. We have seen above that when the number of phases is large the phases in the star branches differ by nearly 90° from those in the corresponding parts of the mesh.

With as small a number of phases as three, the case is different. The use of the diagram *Fig. 2*, discloses the following facts:

In the moment corresponding to position *I* (*Fig. 8*), the current is maximum and positive in *O A*. Let C_s designate this maximum value.

In *O B* and *O C* the currents are both negative and of same value, by reason of symmetry. They are necessarily

$$= -\frac{C_s}{2}$$

In position *II* (*Fig. 9*), which corresponds to one-twelfth

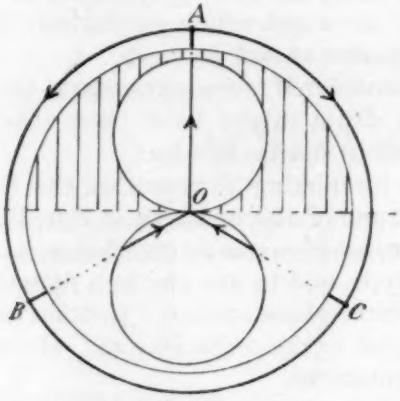

FIG. 8.

period later, or to a displacement of 30° the currents are equal and opposite in *O A* and *O B*.

Their numerical value is

$$\sin 60° \, C_s = \frac{\sqrt{3}}{2} C_s = 0,866 \, C_s$$

At this moment there is no current in *O C*.

In position *III* (*Fig. 10*) [or after another one-twelfth period], the currents are

$$+\frac{C_s}{2}$$

in both *O A* and *O C* and $-C_s$ in *O B*.

The phases and corresponding values of the currents in the branches of the mesh, can be ascertained as follows.

The currents in all conductors are alternating, and since we consider only the case where they follow the *sine* law, we conclude that in position *I*, by reason of symmetry, the current of $O\,A$, which is $= C_s$, divides itself into two equal parts flowing in opposite directions through $A\,B$ and $A\,C$,* so that it is

$$-\frac{C_s}{2}$$

in $A\,B$, and

$$+\frac{C_s}{2}$$

in $A\,C$, if we consider right-hand rotation as positive.

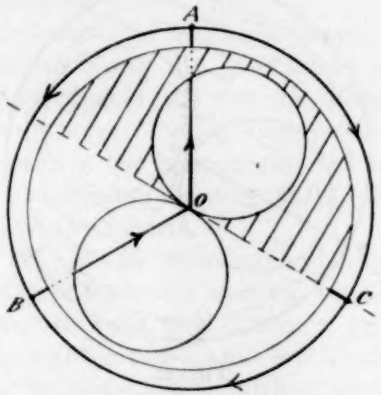

FIG. 9.

There is no current in $B\,C$ at this moment.

As the current in $B\,C$ follows the *sine* law, if it is $= O$ in position *I* it will be maximum one-quarter period or 90° later.

A comparison of *I* and *II* shows that the current is $= O$ in $O\,C$ one-twelfth period or 30° later than in $B\,C$. This means that the difference of phase between the currents in a branch of the mesh and in the adjacent branch of

* It would carry us too far to show that, to assume that the currents in $A\,B$ and $A\,C$ are not equal, is equivalent to assuming that there is a continuous current in the mesh conductors, and this would be contrary to the definition.

the star situated in the negative direction, is 30° or more shortly; the currents in mesh lead those in star by one-twelfth period.

As to the absolute values of the currents in the branches of the mesh, *III* shows that when the current is maximum and

$$= C_s \text{ in } O\ B$$

it is

$$= \frac{C_s}{2} \text{ in } A\ B$$

but the latter is then at one-sixth period, or 60° from its

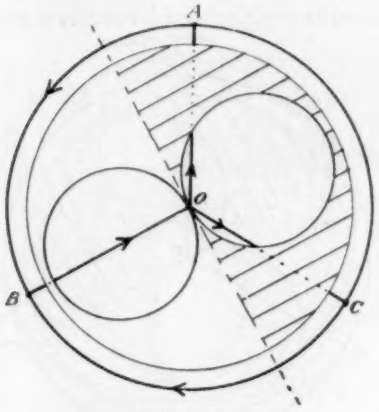

FIG. 10.

zero value. Its maximum value is therefore

$$C_m = \frac{C_s}{2 \sin 60°}$$

or

$$C_m = \frac{1}{\sqrt{3}} C_s = 0{\cdot}577\ C_s$$

The mean currents in the branches of the star and of the mesh are also in this proportion of 1 to 0·577.

A similar process, applied to the differences of potential, would show that those of the mesh lead those of the star by 30°.

The conservation of energy requires that the watts in the

star be equal to those of the mesh, and also that they be equal in one branch of star and one branch of mesh, since everything is symmetrical.

The voltages are, therefore, in inverse proportion of the currents.

The voltage between *O* and *A*, *B* or *C* is $1\sqrt{3}$ or 1,732 times the voltage between *A B*, *B C* or *C A*. This result would not be affected if there was a difference of phase between current and difference of potential, because this difference would be the same throughout. The latter appears from the fact that the relations between the currents can be deducted as above, without reference to the electro-motive force or difference of potential, and vice versa the relations between the difference of potential can be found without reference to the currents.

This fact also shows that whatever the resistances, inductances or capacities along the conductors may be, if the currents in the branches of the star (or, which is the same, in the line conductors) form a symmetrical three-phase system, the currents in the branches of the mesh also form a symmetrical three-phase system shifted by one-twelfth period relatively to the former.

It is obvious that in any symmetrical polyphased system, when the number of phases is uneven, by using each current in two opposite ways (for instance, by leading each current through right-handed and left-handed coils), the same effects can be obtained as with a system of double the number of phases. Thus a three-phase can be made equivalent to a six-phase and the five-phase to a ten-phase, but the four-phase,* since it is an even number, cannot be doubled in this manner. Moreover, as, for the three-phase, the phases in the mesh are shifted by one-twelfth period, relatively, to those in the star, the phases of the mesh come, by a similar process of doubling, exactly between those of the doubled-star currents, and this is true independently of the resistances, etc.

* Four-phase is often called two-phase, while two-phase is, strictly speaking, nothing but an ordinary alternating current.

This enables to obtain with a three-phase system, having only three line conductors, effects equivalent to those of a twelve-phase. The three-phase supersedes in this respect all others, and especially the four-phase, though the latter can also be operated with three-line wires.

[*To be continued.*]

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Johnson, J. B. *Stadia and Earth Work Tables.* New York: J. Wiley & Sons. 1892. 8vo. $1.25.

Madamet, A. *Tiroirs et Distributeurs de Vapeur.* Paris: Gauthier-Villars. 1892. 12mo. 2 francs 5 c.

Magnier de la Source, L. *Analyse des Vins.* Paris: Gauthier-Villars. 1892. 12mo. 2 francs 5 c.

Möller, M. *Das Räumliche Wirken und Wesen der Elektrizität und des Magnetismus.* Hannover-Linden: Manz und Lange. 1892. 8vo.

BOOK NOTICES.

Annuaire pour l'An 1892, publié par le Bureau des Longitudes. Avec des notices scientifiques. Paris: Gauthier-Villars et fils. 1892. Price, 1.50 francs.

The above-named work, published annually under the direction of the "Bureau des Longitudes," corresponds to the official publication known in this country as the *American Ephemeris and Nautical Almanac*. The present impression is characterized by the introduction of the following new features of scientific interest: A table of stellar parallaxes, prepared by M. Loewy; the most recent elements of the satellites of Saturn, according to Struev; additional data in the tables of comets; two new determinations of the orbital elements of double stars, by Glassenapp; additional data respecting the proper movements of stars, including those of certain stars having a very decided proper movement; an article on the stellar spectra, by Cornu, and a note by the same author on the length of the wave of sound; new data by Moureaux on the phenomena of terrestrial magnetism; in addition to which the volume is closed by the introduction of a number of important scientific notes. W.

Volumetric Tables for Pig Iron, Steel and Ore Analysis. By Edward K. Landis. Pottstown, Pa.: Ledger Job Printing Rooms, Pottstown, Pa. 1892.

This is a small volume of thirty pages, containing factors for calculating from the burette readings, the percentage of

(1) Iron;
(2) Lime;
(3) Manganese, determined by William's method;
(4) Manganese, determined by Volhard's method;
(5) Phosphorus, determined by Emmerton's method.

The especial point of interest in the tables is the fact that they are adapted to a $\frac{n}{10}$ solution of permanganate (or bichromate) that *may not be exactly deci-normal.* Thus, in standardizing the solution, suppose that 1·4 grammes of double iron salt require 35·1 cc. $KMnO_4$ (instead of 35·7 cc., as would be required if exactly $\frac{n}{10}$), by turning to the page headed 35·1, we find at once the factors (from 1 to 9) for each of the above five determinations. The book will be appreciated by all iron chemists. It can be had only from the author (address as above) at a cost of 50 cents. P.

PROGRAMME OF LECTURES FOR THE SEASON 1892–93.

The following course of lectures, to be held during the season 1892–93, has been approved:

1892.

Friday,	Nov.	4.	Prof. Lewis M. Haupt, Civil Engineer, Philadelphia, "Ship Canals" (illustrated).
Monday,	"	7.	Prof. H. C. Bolton, New York, "Alchemy, the Cradle of Chemistry" (illustrated).
Friday,	"	11.	Prof. Lewis M. Haupt, Civil Engineer, Philadelphia, "The Road Movement" (illustrated).
Monday,	"	14.	Mr. John Birkinbine, Mining Engineer, President American Institute Mining Engineers, "From Mine to Furnace" (illustrated).
Friday,	"	18.	Mr. J. C. Trautwine, Jr., Civil Engineer, "Movable Dams."
Monday,	"	21.	Mr. George H. Babcock, President Babcock & Wilcox Company, New York, "The Genesis and Exodus of Steam."
Friday,	"	25.	Mr. Eckley B. Coxe, Drifton, Pa., "The Regulation of Wages."
Monday,	"	28.	Mr. C. John Hexamer, Philadelphia, "Austria" (illustrated).
Friday,	Dec.	2.	Mr. James M. Dodge, Link Belt Engineering Company, Philadelphia, "Rope Power Transmissions."

Monday,	Dec.	5.	Prof. H. W. Wiley, Chemist to the Department of Agriculture, Washington, D. C., "Food Adulteration."
Friday,	"	9.	Judson Daland, M.D., Philadelphia, "A New Method of Separating the White from the Red Blood Corpuscles by means of the 'Hæmatokrit.'"
Monday,	"	12.	Mr. T. Commerford Martin, Editor *Electrical Engineer*, New York, "Electricity in the Modern City" (illustrated).
Friday,	"	16.	Mr. Julius F. Sachse, Editor *American Journal of Photography*, Philadelphia, "Philadelphia's Share in the Development of Photography."
Monday,	"	19.	Mr. George Faunce, Superintendent Pennsylvania Lead Company, Pittsburg, Pa., "Electro-Metallurgy and its Applications to Silver Refining and incidentally to other Metals."
Wednesday,	"	28.	Mr. W. N. Jennings, Philadelphia, "Street Scenes caught with the Kodak."
1893.			
Monday,	Jan.	2.	Mr. Pedro G. Salom, Philadelphia, "The Storage Battery Question."
Friday,	"	6.	Mr. W. H. Jaques, Bethlehem Iron Company, Bethlehem, Pa., "Recent Development of Heavy Ordnance in the United States."
Monday,	"	9.	Mr. Emile Berliner, Washington, D. C., "Technical Notes on the Gramophone, with Illustrations."
Friday,	"	13.	Rev. H. C. Hovey, Middletown, Conn., "Castellated Cliffs and Grand Canyons of Arizona" (illustrated).
Monday,	"	16	Mr. George M. Hopkins, New York, "Optical Illusions" (illustrated).
Friday,	"	20.	Prof. George W. Plympton, New York, "The Engineering Features of Egyptian Temple Architecture."
Monday,	"	23.	Dr. Louis Duncan, Johns Hopkins University, Baltimore, Md., "Electric Power Transmission."
Friday,	"	27.	Prof. H. W. Spangler, University of Pennsylvania, Philadelphia, "Cheap Power."
Monday,	"	30.	Prof. Joseph W. Richards, Lehigh University, Bethlehem, Pa., "The Specific Heats of Metals."
Friday,	Feb.	3.	Mr. Alfred R. Wolff, Mechanical Engineer, New York. (Subject to be announced.)
Monday,	"	6.	Mr. Elmer G. Willyoung, with Queen & Co., Philadelphia, "Electricity and the Ether" (illustrated).
Friday,	"	10.	Prof. Charles F. Himes, Dickinson College, Carlisle, Pa., "Expert Testimony."
Monday,	"	13.	Prof. E. D. Cope, University of Pennsylvania, Philadelphia, "Late Additions to our Knowledge of the Evolution of the Mammalia and Man."

Friday,	Feb. 17.	Thomas C. Clarke, Civil Engineer, New York, "Bridging the Hudson and East Rivers."
Monday,	" 20.	Mr. C. Kirchhoff, Editor of *The Iron Age*, New York, "Copper Mining in the United States" (illustrated).
Friday,	" 24.	Mr. Nikola Tesla, New York, "An Experimental Study of Light Effects produced by Alternating High Potentials" (illustrated).
Monday,	" 27.	Mr. Clayton W. Pike, with Queen & Co., Philadelphia, "How we Measure Electricity" (illustrated).

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 21, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 21, 1892.

JOS. M. WILSON, President, in the chair.

Present, eighty-six members and eight visitors.

Elections to membership since last report, twenty-four.

Prof. Edwin J. Houston gave a description of his improved methods of fixing and delineating the magnetic field, illustrating the subject by the projection of views of a series of su-h fields. (See this *Journal*, September, 1892.)

Mr. F. Lynwood Garrison gave an account of some recent trials of Harveyized nickel-steel armor-plate, made by the Bethlehem Iron Company, of Bethlehem, Pa., and tested on the private proving grounds of the company. The results of these trials demonstrated a decided advance in the resisting powers of such plates to the penetration of projectiles. Photographs of these plates taken after the firing test (five shots from an eight-inch gun, powder charge eighty-one and three-fourths pounds, Holtzer projectile weighing 250 pounds). Referring to the last experiment, the speaker stated that the plate (8 x 6 feet x 10½ inches thick and weighing 18,600 pounds), which was a companion piece to one than had lately been tested at the Indian Head proving ground, of which trials a full account appeared in his report published in the *Journal*, had received a total energy of impact of 25,040 foot-tons, fully fifty per cent. greater than the plates were subjected to in the previous trials, and exhibited, nevertheless, much less injury than the plates in the former tests. He considered it doubtful whether armor-plates equal in quality to this had ever been produced elsewhere.

Mr. Louis E. Levy read a paper descriptive of a new process of his invention for producing photo-intaglio engravings, and exhibited specimens of the work, which were greatly admired. The paper elicited considerable discussion and was referred for publication.

Mr. W. N. Jennings exhibited and described several remarkable photographs of lightning which he had obtained during the past summer.

The Secretary described, with the aid of a lantern projection, the Buckman automatic tin-plate machine, and gave an account of its operation at the works of the American Tin-plate Machine and Manufacturing Company, Twentieth and Washington Avenue, Philadelphia. He also exhibited some unusually good specimens of prints in black lines on white ground, made from tracings of line drawings after the general method of making blue prints. These prints were made with a so-called "heliographic" paper prepared by Mr. F. Pontrichet of New York.

The Secretary announced that, with the approval of the Board of Managers, the Committee on Publications was engaged in maturing a plan whereby it is intended that every member of the Institute shall receive the *Journal*, without any increase in the amount of the annual dues. The carrying into effect of this new policy, which, it is believed, will awaken a more general interest in the work of the Institute on the part of its large membership, he explained, was made conditional upon the raising by subscription of a guaranty fund of sufficient amount, to insure that an anticipated deficit in the accounts of the *Journal* during the first few years following the adoption of the new measure, would be amply provided for. The committee, he said in conclusion, entertained no doubt of its ability to obtain the desired guaranty among the members in ample time to introduce the new measure at the beginning of the year 1893.

Mr. Wm. E. Lockwood introduced the following resolution:

WHEREAS, The cities of Chicago and Pittsburg have passed ordinances for the suppression of the smoke nuisance resulting from the use of bituminous coal; and,

WHEREAS, The Councils of the City of Philadelphia are giving consideration to an ordinance of like character.

Resolved, That the Franklin Institute most heartily endorse such action looking to the suppression of a nuisance which is depreciating property in certain localities in the city.

The resolution was duly seconded and was referred to the special committee charged with the investigation of the subject of the smoke nuisance.

Adjourned.

WM. H. WAHL, *Secretary*.